Appendix J
Evaluation of Human Health Effects of Transportation

J.1 INTRODUCTION

The overland transportation of any commodity involve risk to both transportation crew members and members of the public. This risk can result directly from transportation-related accidents and indirectly from the increased levels of pollution from vehicle emissions, regardless of the cargo. The transportation of certain materials, such as hazardous or radioactive substances, can pose an additional risk because of the unique nature of the material itself. To permit a complete appraisal of the environmental impacts of the proposed action and alternatives, the human health risks associated with the transportation of radiological material are analyzed in this appendix.

This appendix provides an overview of the approach used to assess the human health risks that may result from overland transportation. The appendix includes discussion of the scope of the assessment, analytical methods used for the risk assessment (i.e., computer models), assessment assumptions, potential transportation routes, and presents the results of the assessment. In addition, to assist in understanding and interpreting the results, specific areas of uncertainty are described with an emphasis on how the uncertainties may affect comparisons of the alternatives.

The risk assessment results are presented in this appendix in terms of "per-shipment" risk factors, as well as for the total risks for a given alternative. Per-shipment risk factors provide an estimate of the risk from a single shipment. The total risks for a given alternative are found by multiplying the expected number of shipments by the appropriate per-shipment risk factors.

J.2 SCOPE OF ASSESSMENT

The scope of the transportation human health risk assessment, including the alternatives and options, transportation activities, potential radiological and nonradiological impacts, and transportation modes considered, is described below. Additional details of the assessment are provided in the remaining sections of the appendix.

PROPOSED ACTION AND ALTERNATIVES

The transportation risk assessment conducted for this *Draft Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility (Nuclear Infrastructure Programmatic Environmental Impact Statement* [NI PEIS]) estimates the human health risks associated with the transportation of radioactive materials for a number of alternatives.

TRANSPORTATION-RELATED ACTIVITIES

The transportation risk assessment is limited to estimating the human health risks incurred during transportation and handling when away from U.S. Department of Energy (DOE) facilities (i.e., at a port) for each alternative. The transportation risk assessment does not address possible impacts from increased transportation levels on local traffic flow, noise levels, or infrastructure.

Radiological Impacts

For each alternative, radiological risks (those risks that result from the radioactive nature of the materials) are assessed for both incident-free (normal) and accident transportation conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation in the vicinity of a loaded shipment. The radiological risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure to people.

All radiological impacts are calculated in terms of committed dose and associated health effects in the exposed populations. The radiation dose calculated is the total effective dose equivalent (10 CFR Part 20), which is the sum of the effective dose equivalent from external radiation exposure and the 50-year committed effective dose equivalent from internal radiation exposure. Radiation doses are presented in units of roentgen equivalent man (rem) for individuals and person-rem for collective populations. The impacts are further expressed as health risks in terms of latent cancer fatalities and cancer incidence in exposed populations, using the dose-to-risk conversion factors published by the National Council on Radiation Protection and Measurement (NCRP 1993), and by the International Council on Radiation Protection (ICRP 1991).

Nonradiological Impacts

In addition to the radiological risks posed by overland transportation activities, vehicle-related risks are also assessed for nonradiological causes (i.e., causes related to the transport vehicles and not the radioactive cargo) for the same transportation routes. The nonradiological transportation risks, which would be incurred for similar shipments of any commodity, are assessed for both incident-free and accident conditions. The nonradiological risks during incident-free transportation conditions would be caused by potential exposure to increased vehicle exhaust emissions. The nonradiological accident risk refers to the potential occurrence of transportation accidents that directly result in fatalities unrelated to the shipment of cargo. National transportation fatality rates are used in the assessment. Nonradiological risks are presented in terms of estimated fatalities.

Transportation Modes

All overland shipments are assumed to use trucks, those requiring secure shipment will use safe, secure trailer/SafeGuards Transport (SST/SGT). Transatlantic shipments of mixed oxide fuel would use purpose-built ships[1]. Medical isotopes would be shipped via aircraft as well as trucks.

Receptors

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck, ship, and aircraft crew members involved in the actual transportation. The general public includes all persons who could be exposed to a shipment while it is moving or stopped during transit. Potential risks are estimated for the collective populations of exposed people and for the hypothetical maximally exposed individual. The collective population risk is a measure of the radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk is used as the primary means of comparing various alternatives. Persons handling casks at DOE facilities are included in site dose assessments. Workers handling packages at military ports are included in this appendix.

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[1] Purpose-built ships are vessels specifically designed to transport casks containing radioactive material.

J.3 PACKAGING AND REPRESENTATIVE SHIPMENT CONFIGURATIONS

Shipment Configurations Regulations that govern the transportation of radioactive materials are designed to protect the public from the potential loss or dispersal of radioactive materials, as well as from routine radiation doses during transit. The primary regulatory approach to promote safety is through the specification of standards for the packaging of radioactive materials. Because packaging represents the primary barrier between the radioactive material being transported and radiation exposure to the public and the environment, packaging requirements are an important consideration for transportation risk assessment. Regulatory packaging requirements are discussed briefly below. The representative packaging and shipment configurations assumed for this NI PEIS also are described below.

J.3.1 Packaging Overview

Although several Federal and state organizations are involved in the regulation of radioactive material transportation, primary regulatory responsibility resides with the U.S. Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (NRC). All transportation activities must take place in accordance with the applicable regulations of these agencies as specified in 49 CFR and 10 CFR Part 71. Transatlantic shipments would also be in accordance with the International Atomic Energy Agency (IAEA) regulations. DOT and NRC work to ensure that U.S. regulations are consistent with IAEA regulations.

Transportation packaging for small quantities of radioactive materials must be designed, constructed, and maintained to contain and shield their contents during normal transport conditions. For large quantities and for more highly radioactive material, such as spent nuclear fuel, packaging must contain and shield their contents in the event of severe accident conditions. The type of packaging used is determined by the total radioactive hazard presented by the material within the packaging. Four basic types of packaging are used. Excepted, Industrial, Type A, and Type B. Another packaging option, "Strong, Tight," is available for some domestic shipments.

Excepted packages are limited to transporting materials with extremely low-levels of radioactivity. Industrial packages are used to transport materials that, because of their low concentration of radioactive materials, present a limited hazard to the public and the environment. Type A packages are designed to protect and retain their contents under normal transport conditions and must maintain sufficient shielding to limit radiation exposure to handling personnel. These packages are used to transport radioactive materials with higher concentrations or amounts of radioactivity than Excepted, or Industrial packages. Strong, Tight packages are used in the United States for shipment of certain materials with low-levels of radioactivity, such as natural uranium and rubble from the decommissioning of nuclear reactors. Type B packages used to transport material with the highest radioactivity levels, are designed to protect and retain their contents under transportation accident conditions and are described in more detail in the following sections.

J.3.2 Regulations Applicable to Type B Casks

Regulations for the transport of radioactive materials in the United States are issued by DOT and are codified in 49 CFR Part 173. The regulation authority for radioactive materials transport is jointly shared by DOT and NRC. As outlined in a 1979 Memorandum of Understanding with the NRC, DOT specifically regulates the carriers of spent nuclear fuel and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. DOT also regulates the labeling, classification, and marking of all packages. NRC regulates the packaging and transport of spent nuclear fuel for its licensees, which include commercial shippers of spent nuclear fuel. In addition, NRC sets the standards for packages containing fissile materials and spent nuclear fuel.

DOE policy requires compliance with applicable Federal regulations regarding domestic shipments of spent nuclear fuel. Accordingly, DOE has adopted the requirements of 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials," and 49 CFR Part 173, "Shippers–General Requirements for Shipping and Packaging." DOE Headquarters can issue a certificate of compliance for a package to be used only by DOE and its contractors.

J.3.2.1 Cask Design Regulations

Neptunium-237, neptunium-237 targets, mixed oxide fuel, plutonium-238 and many isotopes are transported in robust "Type B" transportation casks that are certified for transporting radioactive materials. Casks designed and certified for spent nuclear fuel transportation within the United States must meet the applicable requirements promulgated by the NRC for design, fabrication, operation, and maintenance, as contained in 10 CFR Part 71.

Cask design and fabrication can only be done by approved vendors with established quality assurance programs (10 CFR Section 71.101). Cask and component suppliers or vendors are required to obtain and maintain documents that prove the materials, processes, tests, instrumentation, measurements, final dimensions, and cask operating characteristics meet the design-basis established in the Safety Analysis Report for Packaging for the cask and that the cask will function as designed.

Regardless of where a transportation cask is designed, fabricated, or certified for use, it must meet certain minimum performance requirements (10 CFR Sections 71.71–71.77). The primary function of a transportation cask is to provide containment and shielding. Casks similar to the designs being considered for targets have been used to transport spent nuclear fuel for many years. Regulations require that casks must be operated, inspected, and maintained to high standards to ensure their ability to contain their contents in the event of a transportation accident (10 CFR Section 71.87). There are no cases of a major release of radioactive materials from a Type B package, even though thousands of shipments have been made by road, rail, and water transport. Further, a number of obsolete casks have been tested under severe accident conditions to demonstrate their adherence to design criteria without failure. Such tests have demonstrated that transportation casks are not only fabricated to a very high factor of safety, they are even sturdier than required.

Transportation casks are built out of heavy, durable structural materials such as stainless steel. These materials must ensure cask performance under a wide range of temperatures (10 CFR Section 71.43). In addition to the structural materials, shielding is provided to limit radiation levels at the surface and at prescribed distances from the surface of transportation casks (10 CFR Section 71.47). Shielding typically consists of dense material such as lead or depleted uranium. However, heavily shielded casks are needed for targets because irradiated targets have gamma radiation levels similar to those of spent fuel. The cask cavity can be configured to hold various contents, including irradiated or unirradiated targets. The assemblies are supported by internal structures, called baskets, that provide shock and vibration resistance and establish minimum spacing and heat transfer to maintain the temperature of the contents within the limits specified in the Safety Analysis Report for Packaging.

Finally, to limit impact forces and minimize damage to the structural components of a cask in the event of a transportation accident, impact-absorbing structures may be attached to the exterior of the cask. These are usually composed of foam, or aluminum honeycomb that is designed to readily deform upon impact to absorb impact energy. All of these components are designed to work together in order to satisfy the regulatory requirements for a cask to operate under normal conditions of transportation and maintain its integrity in an accident.

J.3.2.2 Design Certification

For certification, Type B transportation casks must be shown by analysis and/or testing to withstand a series of hypothetical accident conditions. These conditions have been internationally accepted as simulating damage to transportation casks that could occur in most reasonably foreseeable accidents. The impact, puncture, fire, and water-immersion tests are considered in sequence to determine their cumulative effects on one package. These accident conditions are described in **Figure J–1**. NRC issues regulations, 10 CFR Part 71, governing the transportation of radioactive materials. In addition to the tests shown in Figure J–1, the regulations affecting Type B casks require that a transportation cask with activity greater than 10^6 curies (which is applicable to irradiated targets) be designed and constructed so that its undamaged containment system would withstand an external water pressure of 20 kilograms per square centimeter (290 pounds per square inch) or immersion in 200 meters (656 feet) of water, for a period of not less than 1 hour without collapsing, buckling, or allowing water to leak into the cask.

Under the Federal certification program, a Type B packaging design must be supported by a Safety Analysis Report for Packaging, which demonstrates that the design meets Federal packaging standards. The Safety Analysis Report for Packaging must include a description of the proposed packaging in sufficient detail to identify the packaging accurately and provide the basis for evaluating its design. The Safety Analysis Report for Packaging must provide the evaluation of the structural design, materials properties, containment boundary, shielding capabilities, and criticality control, and present the operating procedures, acceptance testing, maintenance program, and the quality assurance program to be used for design and fabrication. Upon completion of a satisfactory review of the Safety Analysis Report for Packaging to verify compliance to the regulations, a Certificate of Compliance is issued.

J.3.2.3 Transportation Regulations

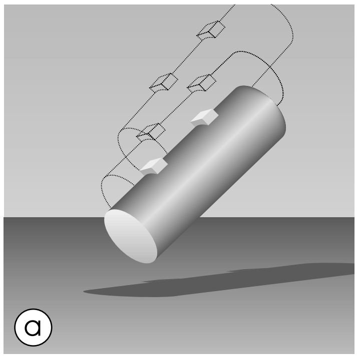
To ensure that the transportation cask is properly prepared for transportation, trained technicians perform numerous inspections and tests (10 CFR Section 71.87). These tests are designed to ensure that the cask components are properly assembled and meet leak-tightness, thermal, radiation, and contamination limits before shipping radioactive material. The tests and inspections are clearly identified in the Safety Analysis Report for Packaging and/or the Certificate of Compliance for each cask. Casks can only be operated by registered users who conduct operations in accordance with documented and approved quality assurance programs meeting the requirements of the regulatory authorities. Records must be maintained that document proper cask operations in accordance with the quality requirements of 10 CFR Section 71.91. Reports of defects or accidental mishandling must be submitted to the NRC. DOE would be the Shipper-of-Record for the shipments.

External radiation from a package must be below specified limits that minimize the exposure of handling personnel and the general public. For an exclusive-use shipment (i.e., carrying no other cargo) in a closed transport vehicle, the external radiation dose rate during normal transportation conditions must be maintained below the following limits of 49 CFR Part 173:

- 10 millirems per hour at any point 2 meters (6.6 feet) from the vertical planes projected by the outer lateral surfaces of the transport vehicle (referred to as the regulatory limit throughout this document)

- 2 millirems per hour in any normally occupied position in the transport vehicle

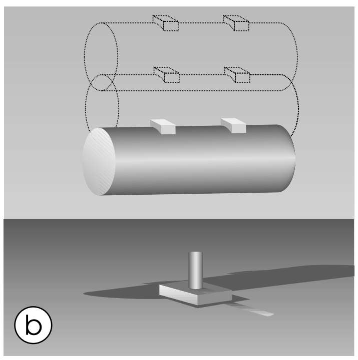
Additional restrictions apply to package surface contamination levels, but these restrictions are not important for the transportation radiological risk assessment. For risk assessment purposes, it is important to note that all packaging of a given type is designed to meet the same performance criteria. Therefore, two different



STANDARDS FOR TYPE B CASKS

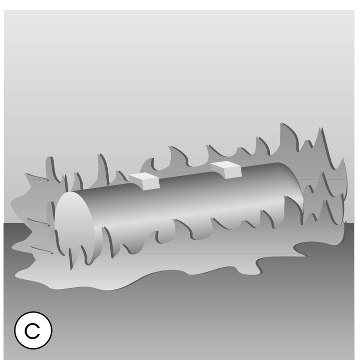
For certification by NRC, a cask must maintain its integrity under routine transportation conditions and be shown by test or analysis to withstand a series of accident conditions without releasing its contents. These conditions have been internationally accepted as simulating damage to casks that could occur in most severe credible accidents. The impact, fire, and water-immersion tests are considered in sequence to determine their cumulative effects on one package. A separate cask is subjected to a deep water-immersion test.

a **Free Drop (Impact):** A 30-foot drop onto a flat, unyielding surface so that the package's weakest point is struck.

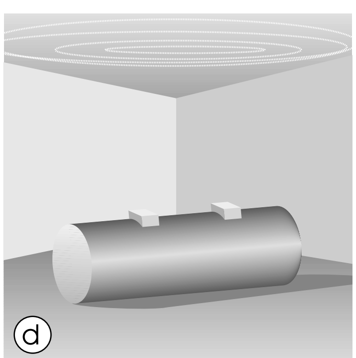


b **Puncture:** A 40-inch free drop onto a 6-inch diameter steel rod at least 8 inches long, striking the package at its most vulnerable spot.

Crush: For some low-density, light-weight packages, a drop of a 1,100-pound mass from 30 feet onto the package resting on an unyielding surface is required.



c **Heat:** Exposure of the entire package to 1,475 °F for 30 minutes.



d **Immersion (fissile materials):** Package immersed under 3 feet of water in a position where maximum leakage is expected.

Immersion (all packages): A separate, undamaged package is submerged under 50 feet of water.

Additionally, 10 CFR 71.61 requires irradiated nuclear fuel packages (separate and undamaged) to be subjected to pressure that relates to a water depth of greater than 600 feet.

Source: Adapted from DOE 1999.

Note: 1 foot = 0.3048 meters; 1 inch = 2.54 centimeters; °F = (1.8 x °C) + 32.

Figure J–1 Standards for Transportation Casks

Type B designs would be expected to perform similarly during incident-free and accident transportation conditions. The specific containers selected or designed, however, will determine the total number of shipments necessary to transport a given quantity of material.

J.3.2.4 Communications

Proper communication assists in ensuring safe preparation and handling of transportation casks. Communication is provided by labels, markings, placarding, shipping papers, or other documents. Labels applied to the cask, document the contents and the amount of radiation emanating from the cask exterior, known as the transport index (49 CFR Section 172.403). The transport index lists the ionizing radiation level in millirems per year at a distance of 1 meter (3.3 feet) from the cask surface.

In addition to the label requirements, markings (49 CFR Section 173.471) should be placed on the exterior of the cask to show the proper shipping name and the consignor and consignee in case the cask is separated from its original shipping documents (49 CFR Section 172.203). Transportation casks are required to be permanently marked with the designation "Type B," name and address of the owner or fabricator, Certificate of Compliance number, and the gross weight (10 CFR Section 71.83).

Placards are applied to the transport vehicle or freight container holding the transportation cask (49 CFR Section 172.500). The placards indicate the radioactive nature of the contents. Neptunium-237, neptunium-237 targets and plutonium-238 shipments which constitute a highway route-controlled quantity or "HRCQ," must be placarded according to 49 CFR Section 172.507. Placards provide first responders to a traffic or transportation accident with initial information about the nature of the contents.

Shipping papers should contain the notation "HRCQ" and have entries identifying the following: name of the shipper, emergency response telephone number, description of contents, and the shipper's certificate, as described in 49 CFR Part 172, Subpart C.

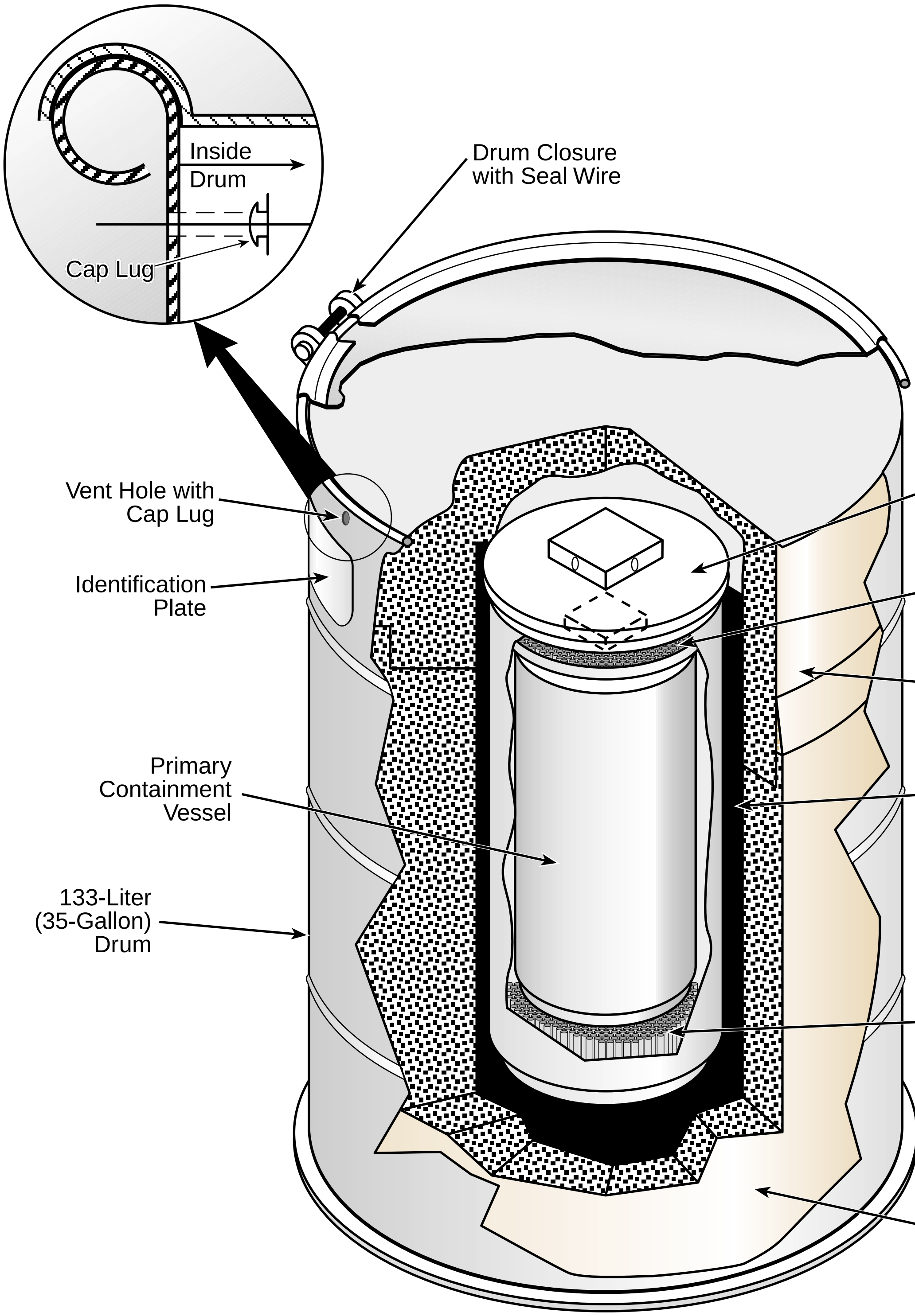
In addition, drivers of motor vehicles transporting radioactive material must have training in accordance with the requirements of 49 CFR Section 172.700. The training requirements include familiarization with the regulations, emergency response information, and the hazard communication programs required by the Occupational Safety and Health Administration in 29 CFR Section 1910.1200. Drivers are also required to have training on the procedures necessary for safe operation of the vehicle.

J.3.3 Packages Used in the Nuclear Infrastructure Program

This section describes currently available packaging systems that have been used for similar materials and could be used to implement the activities described in this NI PEIS. DOE could choose to design new or procure similar packaging. This similar packaging would be designed to the same level of safety and would be expected to have similar features. These packages have been used for the purpose of estimating input parameters, such as number of shipments and mass of contents, for the purpose of impact analysis.

J.3.3.1 Neptunium-237 Packaging

The Type B 9975 container could be used to transport neptunium-237 from the Savannah River Site (SRS) to the storage or processing facility the Radiochemical Engineering Development Center (REDC), Fluorinel Dissolution Process Facility (FDPF), or Fuels and Materials Examination Facility (FMEF). The 9975 package includes a 132-liter (35-gallon) drum, insulation, bearing plates, primary containment vessel, secondary containment vessel, lead shielding and aluminum honeycomb spacers (**Figure J–2**). The weight of the



Source: WSRC 1996.

Figure J–2 Typical Assembly of Type 9975 Package

package is 163 kilograms (360 pounds), the overall height is 0.9 meter (35 inches) and the diameter is 0.5 meter (20 inches) (WSRC 1996).

In the spring of 2000, the 9975 packaging failed the recertification test and the Certificate of Compliance has been canceled. During the sequential 30-foot drop and puncture bar test, which are part of the hypothetical accident condition testing, the package lid buckled and partially opened. DOE could either redesign the 9975 package, design a new package or modify an existing package. In any case, the new design would be evaluated for compliance with current regulatory requirements by the Package Approval and Safety Program. DOE needs a package of similar size and capability to the 9975 for several programs, including the Rocky Flats cleanup (Scott 2000). The size and general characteristics of the replacement package (i.e., 132-liter [35-gallon] or 206-liter [55-gallon] drum, can-in-can construction, insulation, approximately 5-kilogram capacity) would be similar to the 9975. Therefore, for the purpose of risk analysis, the capacity and general characteristics of the 9975 package will be used.

The neptunium-237 would be sealed into a convenience can and placed on a honeycomb spacer inside the stainless steel primary containment vessel. The primary containment vessel would be bolted closed, and placed into the similarly constructed, but larger, secondary containment vessel. The secondary containment vessel would be bolted closed and loaded into the drum. The drum is equipped with lead shielding that reduces radiation levels, and fiberboard insulation that protects the containment vessels in the unlikely event of a severe impact. The drum and cover are made of 18-gage carbon steel and are galvanized and coated with zinc chromate. A locking ring with drop-forged lugs secures the cover to the drum.

The impact analysis for neptunium-237 shipments will be based on the available storage volume at REDC at the Oak Ridge Reservation (ORR). FDPF and FMEF have adequate storage volumes for this amount of neptunium-237. REDC plans 35 storage tubes with a useable length of 9.1 meters (30 feet) and 5 tubes with a useable length of 2.4 meters (8 feet). Each 10-inch storage can holds a maximum of 1.5 kilograms (3.3 pounds) of neptunium-237. This allows room for storage of 1,960 kilograms (4,321 pounds) of neptunium-237. Based on 20 kilograms (44 pounds) per SST/SGT shipment, it will take 98 trips to move the neptunium-237 from SRS to REDC. Each SST/SGT would carry about 14 containers containing a storage can on board.

J.3.3.2 Neptunium Targets

After targets are fabricated at the processing facility, located at the REDC at ORR, FDPF at the Idaho National Engineering and Environmental Laboratory (INEEL), or FMEF at Hanford, they will be transported to either the High Flux Isotope Reactor (HFIR) at ORR, Advanced Test Reactor (ATR) at INEEL, Fast Flux Test Facility (FFTF) at Hanford, a new reactor or a new accelerator, or a commercial light water reactor (CLWR) for irradiation. After they are irradiated, they will be returned to the processing facility for extraction of the plutonium-238. The same casks and number of shipments will apply to both the unirradiated and irradiated targets.

Intrasite Shipment—REDC to HFIR or FDPF to ATR

If HFIR is selected to irradiate and REDC to process the targets, targets would be transported the short distance between REDC and HFIR in a cask that was formerly certified to Type B standards. These formerly certified packages are verified to be equivalent to Type B packages by site procedures. Since the move is only about 90 meters (100 yards), on closed roads, and entirely at ORR, DOE procedures and NRC regulations do not require the use of a certified Type B cask. Similar procedures and equipment would be used at INEEL for transfers between FDPF and ATR.

INTERSITE SHIPMENT

The transportation of irradiated targets would involve shipments of Type B quantities (based on activation levels) using NRC or DOE certified shipping casks. The amount of material that can be loaded in a shipping cask is controlled by the thermal load, the fission product inventory, the neutron dose rate and the physical size. Although a new cask could be designed for this application, the most likely approach would be to design a new basket to fit inside an existing cask. Since this design effort is not yet underway, the exact number of shipments cannot be determined. As an example case, if the GE–2000 container (**Figure J–3**) is used, the thermal load limit would determine the total number of shipments. Transportation of the irradiated targets is likely to require updating the Certificate of Compliance for the casks. Preliminary calculations to determine the decay heat were done for several irradiation positions and cycles to estimate the thermal load of the irradiated targets. The preliminary analysis indicates that irradiated targets that have cooled for at least 100 days will generate about 0.58 watt (0.033 British thermal unit per minute) of heat for each gram (0.035 ounce) of plutonium-238. If the targets are classified as spent nuclear fuel, then the thermal load limit for the GE–2000 cask is 600 watts (34 British thermal units per minute) per shipment. In this case, a total of nine shipments would be required to move the targets. If the targets are classified as a by-product or special nuclear material, then the thermal load limit is 2,000 watts (114 British thermal units per minute) per shipment for a total of three shipments. Thus, the range is roughly three to nine shipments per year, and the risk analysis is based on nine shipments per year. This range is representative of other commercially available casks. Note that the GE–2000 is too large and heavy to transport on an SST/SGT.

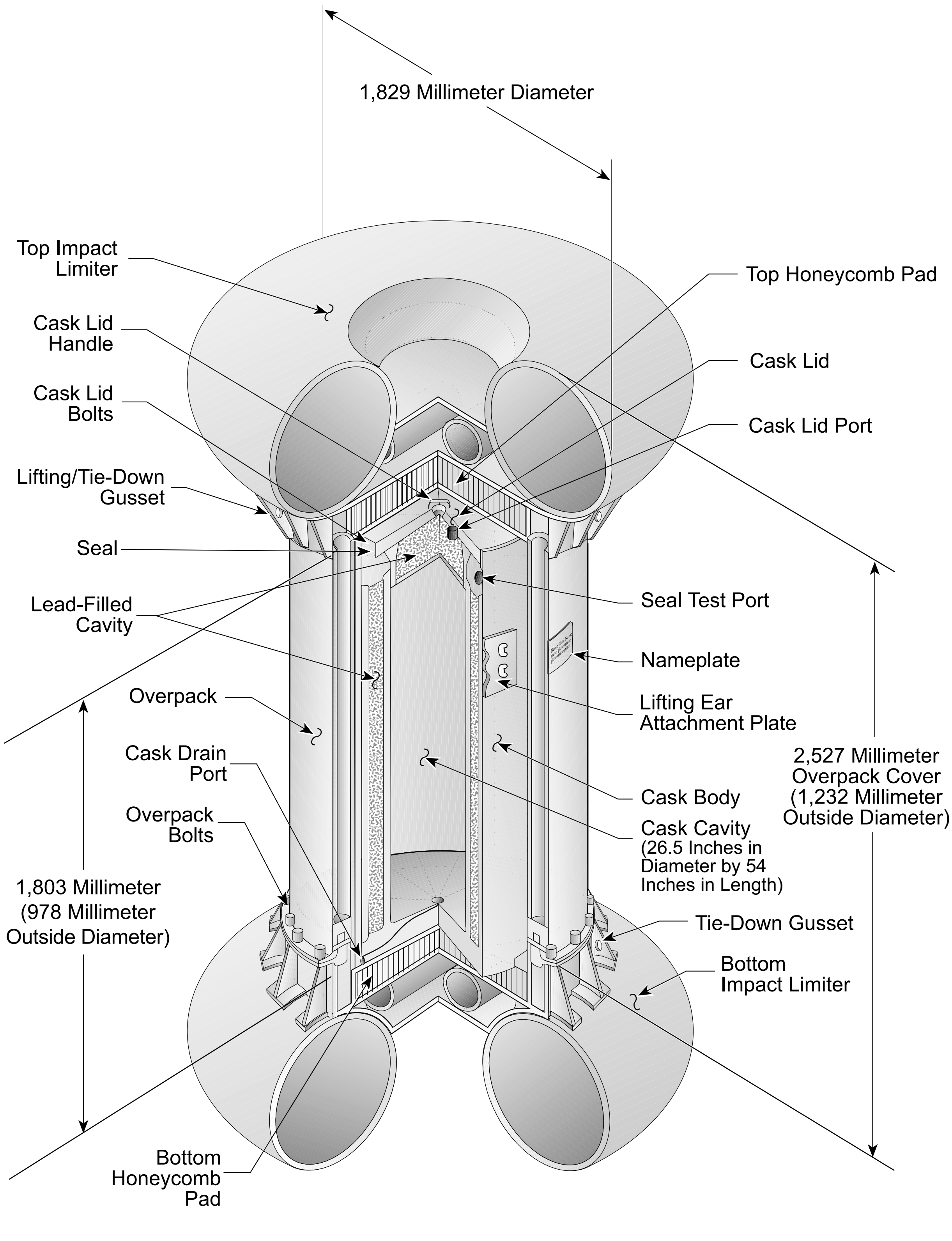
DOE realizes that a CLWR, new reactor, accelerator, or FFTF would use larger targets than HFIR or ATR. A GE–2000 container would not be long enough for these targets. However, about the same thermal parameters would apply for all but the accelerator targets, so the same shipping estimates are used. Based on the preconceptual design, accelerator targets would be much larger, but would require fewer shipments.

J.3.3.3 Plutonium-238

The 5320 cask, designed for shipment of americium or plutonium by surface transportation modes could be used to carry plutonium-238 oxide that would be produced at the processing facility. Several versions of the 5320 (the 5320 B(U) and the 5320 B(M)) comply with the regulatory safety requirements of 10 CFR Part 71, as well as DOE and IAEA requirements. The 5320 package was evaluated for transport of plutonium-238 oxide in any solid form, in excess of Type A quantities as Fissile Class I. The radioactive content is limited to 357 grams (12.6 ounces) of plutonium-238. When the only plutonium isotope is plutonium-238, the 5320 packages may be shipped Fissile Exempt, subject to the provisions of 49 CFR Section 173.453(f). The plutonium-238 oxide may be any density up to 11 grams per cubic centimeter (6.4 ounces per cubic inch), contain a maximum of 1 gram of volatile constituents, and not exceed a decay heat load of 203 watts (11.6 British thermal unit per minute). The time that the plutonium-238 can be sealed within the primary containment vessel prior to and including shipment is limited to 2 years.

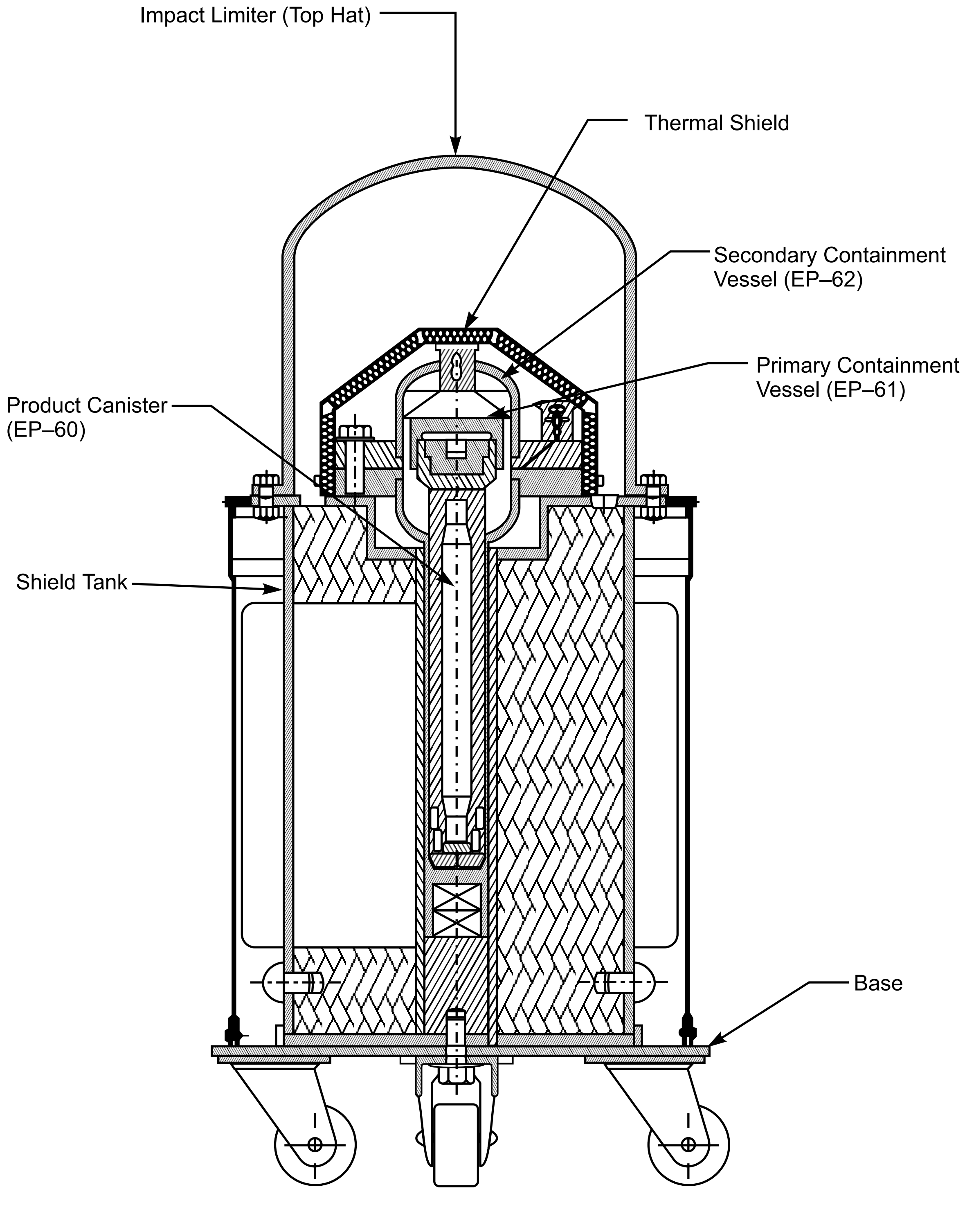
The 5320 packaging is a dome topped, upright circular cylinder mounted on a baseplate supported by casters, as shown in **Figure J–4**. The weight of the packaging is about 148 kilograms (327 pounds), the overall height is 81 centimeters (32 inches) and the diameter is 42.5 centimeters (16.75 inches).

The plutonium-238 would be loaded into an EP–60 product canister. The EP–60 is not credited in the safety analysis as part of the packaging. It is a stainless steel shell confinement vessel which is used to load the product into the package safely and conveniently. The EP–60 would be seal welded into the removable stainless shell primary containment vessel, the EP–61. The EP–61 is placed into the secondary containment vessel, the EP–62. The stainless steel EP–62 has a removable bolted closure lid. The gasketed flange of the EP–62 satisfies the containment requirements of normal conditions of transport and hypothetical accident



Source: DOE 1996.

Figure J–3 GE–2000 Container



Source: Adapted from DOE 2000.

Figure J–4 Cross Section of 5320 Packaging Assembly

conditions. Shipments must be completed within 2 years of sealing the EP–61 because of the possibility of undetected gas buildup.

The nested EP–61 and EP–62 are surrounded by a tinned aluminum-shield tank filled with water-extend polyester neutron shielding material. The EP–62 is retained with the inner shell of the shield tank by a bolt which fastens the bottom of the vessel to the baseplate. Heat from the package contents is conducted to the outer shell of the shield tank by radial aluminum webs that connect the inner shell to the outer shell. Axial fins on the outer shell dissipate the heat to the environment.

DOE estimates that one shipment per year would support the operational requirements for 5 kilograms (11 pounds) of plutonium per year. Based on the heat limit of the cask, 203 watts (11.6 British thermal units per minute), the casks would be loaded with up to 350 grams (12 ounces) of plutonium-238. Therefore, each SST/SGT shipment would carry about fifteen 5320 casks.

The *Environmental Assessment of the Import of Russian Plutonium-238* (DOE 1993) analyzed the smaller Mound 1-kilowatt packages. These packages were actually used for two successful shipments. The risk analysis results from that environmental assessment have been used in this NI PEIS.

J.3.3.4 Irradiated Target Assembly Packages for Medical and Industrial Isotopes

Although there are two different target vehicles, the long irradiated target vehicle (up to 1 meter [3 feet] in length) and the rapid retrieval target vehicle (up to 20 centimeters [8 inches] in length), both irradiation vehicles would be shipped from FFTF at Hanford to the Radiochemical Processing Laboratory (RPL) at Hanford using the T–2 shipping cask. The elements or pins from the long irradiation target vehicles would be inserted directly into the shipping cask, whereas the rapid retrieval targets would be inserted into a smaller package, which would be inserted into the shipping cask. For the purposes of this analysis, it is assumed that the elements or pins from one assembly (i.e., carrying a single target isotope and its associated impurities), would be shipped at a time. Similar packages would be used at the new reactor or accelerator facility.

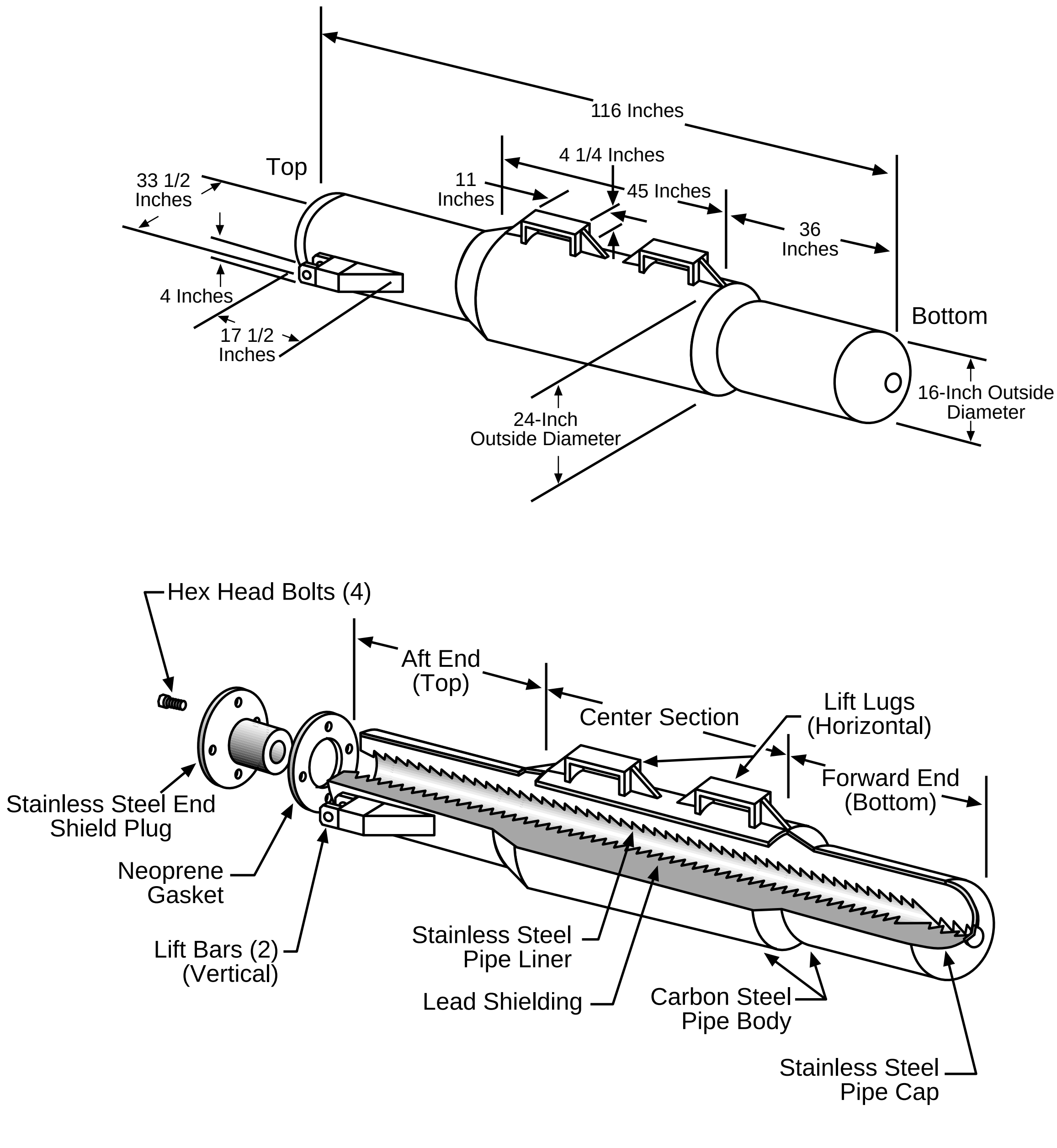
J.3.3.4.1 Long-Length Irradiated Target Vehicle Shipping Cask

The long-length irradiated target shipping cask would be used for transporting irradiated targets. A typical example for this type of casks is the T–2 shipping cask (**Figure J–5**). This cask has been used at Hanford in the past and is certified to carry sodium-bonded metal fuel pins. The T–2 meets the requirements for a Type B shipping package.

The T–2 cask is 295 centimeters (116 inches) long with a 254-centimeter (100-inch) long by 15-centimeter (6-inch) inner diameter liner made of schedule 40 stainless steel pipe. The outside shell of the cask is made in three sections. The center section is a 61-centimeter (24-inch) outer diameter schedule 40 carbon steel pipe. Each end section is made of 41 centimeter (16 inch) outer diameter schedule 40 carbon steel pipe. The space between the liner and shell is filled with lead for shielding. At the top, there is a 19-centimeter (7-5/8-inch) inner diameter opening which is closed by a 20-centimeter (8-inch) thick stainless steel shield plug. Figure J–5 shows the cross section of a T–2 cask and its dimensions. The cask is enclosed in a steel shipping case during transport (Lavender and Nielsen 1997).

J.3.3.4.2 Rapid Retrieval Target Vehicle Package

The rapid retrieval targets would be packaged in a container and inserted in the T–2 shipping cask for transport to RPL from FFTF. A "shielded pig" or sample pig would be used for packaging the rapid retrieval targets. For the purposes of this analysis, the proposed "shielded pig" is assumed to be 122 centimeters (48 inches)



Source: Lavender and Nielsen 1997.

Figure J–5 T–2 Shipping Cask: Long-Length Irradiated Target

tall by 15 centimeters (6 inches) in diameter. Based on existing sample pig design information, the "shielding pig" inner and outer walls will be constructed with schedule 40 carbon steel pipe. Lead shielding would be provided between the inner and outer carbon steel pipes in a "sandwich" configuration. The T–2 would be equipped with spacers to prevent the movement of the sample pig within the T–2 cask cavity. Smaller (i.e., shorter) shielded pigs have been approved for use at Hanford in the past. It is anticipated that the longer shielded pig proposed for the transport of the rapid retrieval targets would also be approved for use at Hanford (Lavender and Nielsen 1997).

J.3.3.5 Packages for Separated Medical Isotopes

DOE has been producing and shipping medical and industrial isotopes for several decades. This NI PEIS proposes alternatives that expand the amount and number of isotopes that DOE can supply for its customers (ultimately to hospitals, research laboratories, and other private and government users of isotopes). Alternatives proposed in this NI PEIS pose no new shipping issues or requirements for package development. Various Type A and Type B containers could be used for shipping the separated isotopes from Pacific Northwest National Laboratory (PNNL) to the pharmaceutical distributor. Following target processing, the separated isotopes, either as liquids, gases or solids, would be placed in glass vials and inserted into the protective container. For this analysis, it is assumed the CI-20WC-2A would be used for the separated isotope shipments. The CI-20WC-2A is a specification package, constructed and used in accordance with 49 CFR Section 178.362.

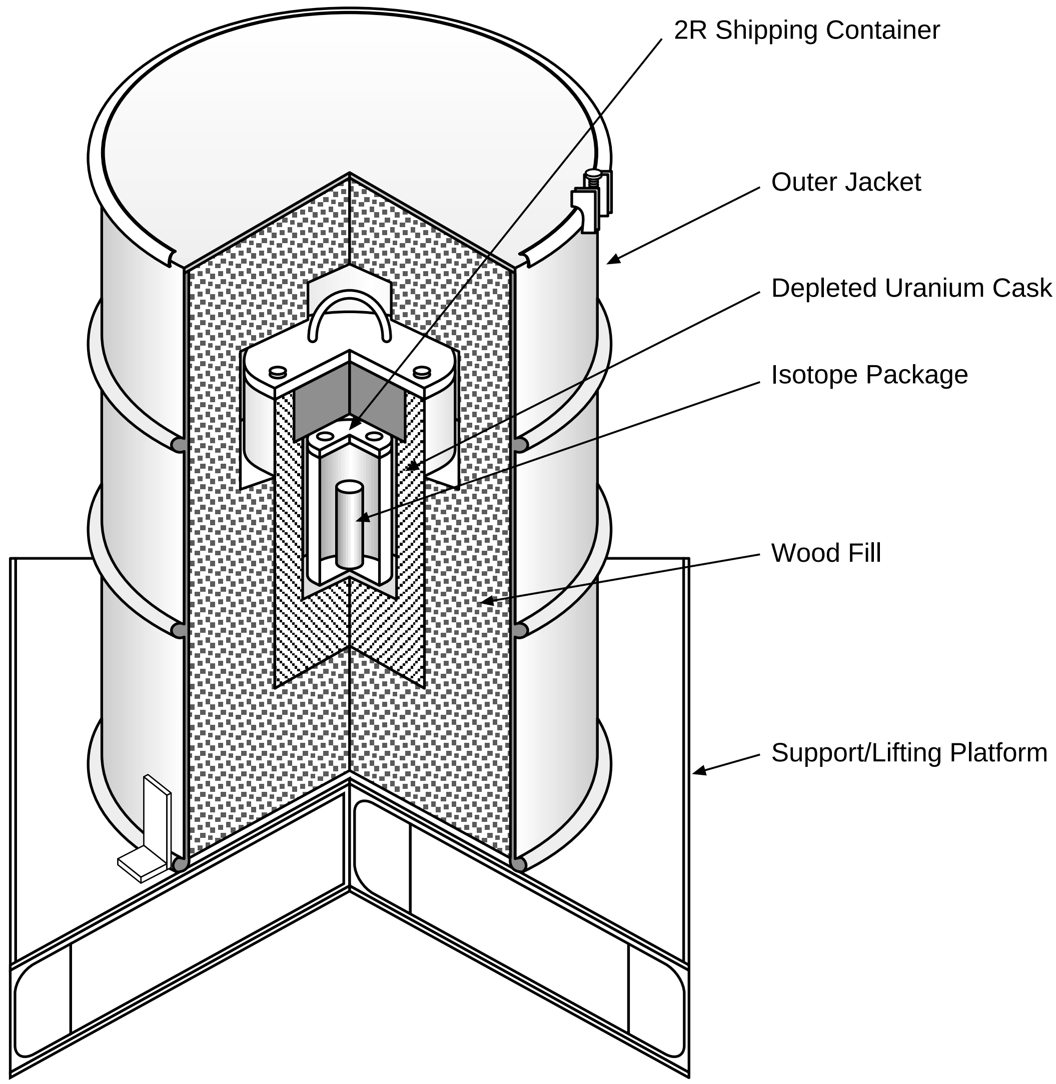
The CI-20WC-2A container, shown in **Figure J–6**, consists of an outer steel jacket, 62 centimeters (24.25 inches) high by 46 centimeters (18 inches) in diameter and an inner depleted uranium shipping cask, 22.9 centimeters (9 inches) high by 11.4 centimeters (4.5 inches) in diameter and 4.6 centimeters (1.8 inches) thick. Between the outer steel jack and the depleted uranium cask is a wooden impact limiter 14.0 centimeters (5.5 inches) thick on the sides, top, and bottom. The inner and outer walls of the depleted uranium cask are constructed of schedule 40 carbon steel pipe with a gasketed and bolted flange closure. The inner cavity of the depleted uranium cask, which is designed to accept a 2R shipping container, is 15.2 centimeters (6 inches) high and 7.9 centimeters (3.1 inches) in diameter.

The 2R shipping container is a 6.9-centimeter (2.7-inch) outer diameter by 14.1-centimeter (5.6-inch) long stainless steel, gasketed and threaded container. Spacers would be placed within the 2R shipping container to limit the movement of the glass vial containing the separated isotope (Lavender and Nielsen 1997).

J.3.3.6 Mixed Oxide Fuel Package

Two European casks could be considered for shipping the SNR–300 mixed oxide fuel to FFTF. The major characteristics are:

1. The British cask GB/136 (owned by AEA Technologies)
   - Capacity is four assemblies per cask
   - 16 casks are available
   - Activity: less than 400 kilocuries
   - Heat load: less that 400 watts
   - Head load/assembly: less than 150 watts
   - Heat load may limit to only two to three assemblies in some casks
   - Quantity of casks makes this cask system desirable



Source: Lavender and Nielsen 1997.

Figure J–6 CI-20WC-2A Shipping Casks: Separated Isotopes

2. The SNR–300 fuel assembly cask
    - Capacity is nine assemblies per cask
    - 2 casks are available
    - Activity: less than 57 kilocuries
    - Heat load/assembly: less than 115 watts
    - Capacity, and with this cask being built for this fuel, makes this cask system desirable

Neither of the casks are currently certified by DOE, NRC, or DOT for use in the United States. SBK of Germany, owner of the SNR–300 fuel, could obtain a DOT Certificate of Competent Authority for either cask (Hiller 2000). Alternatively, SBK could select an existing cask for modification or design a new cask. For the purpose of conservative analysis, DOE assumes that two assemblies are shipped in each Type B package.

The shielding and accident performance parameters used in the impact analysis are typical for Type B packages.

J.3.3.7 Highly Enriched Uranium Package

DOE has several Type B packages that could be used to ship highly enriched uranium oxide to the fuel fabricator. The two identified packages are DT-22 and DC-1. Several other packages are used in normal commercial shipment of highly enriched uranium and could be used in this application.

J.3.3.8 Highly Enriched Uranium Fuel Packages

Alternatives 1 (Restart FFTF) and Alternative 4 (Construct New Research Reactor) would require packages for delivering fresh uranium fuel to the sites. Package selection cannot be made at this time, so this section will describe the general characteristics of packages that would be used. The driving requirement comes from 10 CFR Section 71.55 (e), stating "A package used for the shipment of fissile material must be so designed and constructed and its contents so limited that under the tests specified in 10 CFR Section 71.73 ("Hypothetical accident conditions"), the package would be subcritical." A criticality analysis would have to be performed to design the packages.

Highly Enriched Uranium Fuel for FFTF

FFTF can use highly enriched uranium or mixed oxide fuel. For all options in Alternative 1, FFTF would require highly enriched uranium fuel for part of it's mission. DOE estimates that FFTF would use 12 to 15 fuel assemblies per year containing about 26.5 kilograms (16.5 pounds) of 35 percent enriched uranium. These quantities of uranium would require Type B packages to withstand the hypothetical accident conditions defined in 10 CFR Part 71. A reasonably large Type B package would hold four assemblies, and would be carried alone on a truck. Alternatively, two smaller Type B packages, each holding two assemblies, could be used. In either case, the same number of shipments would be required.

J.3.3.9 Nuclear Research and Development Materials Test Transport

The T–3, an existing licensed DOT irradiated fuel shipping cask is available for offsite transportation (e.g., shipment of fueled tests to other DOE facilities for diagnostic examinations). This cask can accommodate shipments of pins or a single FFTF fuel assembly, as well as non-fuel experiments and materials. There are three of these casks available for shipping material within the fuel descriptions of approved packages shown in the T–3 Certificate of Compliance, or for anyone willing to pay for the addition of new packages through an addendum to the NRC Certificate of Compliance. Equipment is available to use the T–3 cask in either the horizontal or the vertical position. Following are some facts about the T–3 cask:

- NRC License, docket no. 71–9132
- DOT Certificate (IAEA Certificate of Compliance)
- DOE License from 1998–1999
- Designed to meet all licensing requirements of 10 CFR Part 71 for a Fissile Class III, Type B shipping container
- 17,300 kilograms (38,200 pounds) gross weight for a loaded container; overall package weight, 19,296 kilograms (42,595 pounds)
- 67 centimeters (26 inches) in diameter by 450 centimeters (177 inches) long overall cask dimensions
- 20 centimeters (8 inches) in diameter by 373 centimeters (147 inches) long internal cavity dimensions
- 0.1 cubic meters (4.3 cubic feet) - cavity volume
- 1400 watts - (80 British thermal units per minute) maximum decay heat for contents

- 320 kilograms (700 pounds) maximum weight of contents
- Designed and fabricated to meet ASME Section III (1977 ed.)
- Design allows shipping intact FFTF standard core components (control rods, reflector, experiments, etc.)
- Design envelope includes use of fuel pin containers (irradiated fuel pins)
- Design allows for handling of hardware shipping containers (irradiated hardware)

No specific shipments or mission has been identified for this cask, however it is included as a general purpose package available on Hanford.

J.3.4 Safeguarded Transportation

DOE anticipates that any transportation of neptunium, plutonium dioxide, mixed oxide fuel, or highly enriched uranium would be required to be made through use of the Transportation Safeguards System and shipped using SST/SGTs. Transportation safeguards are required for (1) nuclear explosives; (2) components moved in a single shipment that could comprise a complete nuclear explosive; (3) any form of uranium-235 enriched 20 percent or greater in quantities of 5 kilograms or more, or uranium-233 or plutonium in quantities of 2 kilograms or more; (4) classified forms of plutonium and uranium-235 regardless of quantity as requested by Heads of Field Elements; (5) DOE-owned plutonium in any quantity to be transported by air; or (6) any form of plutonium-238 in excess of 5 grams (DOE Order Supplemental Directive AL 5610.14). The SST/SGT is a fundamental component of the Transportation Safeguards System. The Transportation Safeguards System is operated by the DOE Transportation Safeguards Division of the Albuquerque Operations Office for the DOE Headquarters Office of Defense Programs. Based on operational experience between fiscal year 1984 and fiscal year 1998, the mean probability of an accident requiring the tow-away of the SST/SGT was 0.058 accident per million kilometers (0.096 accident per million miles). By contrast, the rate for commercial trucking in 1989 was about 0.3 accident per million kilometers (0.5 accident per million miles) (Claus and Shyr 1999). Commercial trucking accident rates (Saricks and Tompkins 1999) were used in the human health effects analysis. Since its establishment in 1975, the Transportation Safeguards Division has accumulated more than 151 million kilometers (94 million miles) of over-the-road experience transporting DOE-owned cargo with no accidents resulting in a fatality or release of radioactive material.

Neptunium must be handled under the safeguards applicable to special nuclear materials, in accordance with DOE Office of Safeguards and Security guidance (McCallum 1999). Pure neptunium is a form of neptunium that would be desirable as a potential weapons material, so this NI PEIS assumes that the neptunium shipped from SRS to the storage locations would need to be shipped under the Transportation Safeguards System. The unirradiated and irradiated targets would carry much less neptunium per shipment, and the form of the neptunium would be less desirable for diversion, so this NI PEIS assumes that the neptunium shipped from SRS to the storage locations might be shipped under the Transportation Safeguards System program. The unirradiated and irradiated targets carry much less neptunium per shipment, and the neptunium is in a less desirable form, so the safeguards requirements would be lower. DOE's policy is to ship DOE-owned Safeguard Categories I and II quantities of special nuclear material and other forms and quantities of strategic materials under the safeguards protection of the Transportation Safeguards System program (DOE Order 5610.14). DOE Order 474.1, *Control and Accountability of Nuclear Materials* contains the methodology for determining the Safeguards Categories of the various nuclear materials that DOE handles. The highly enriched uranium, the highly enriched uranium fuel and mixed oxide fuel required for operation of FFTF will be transported under safeguards protection.

Although DOE may choose to use the Transportation Safeguards System program for unirradiated and irradiated target shipments, for the purposes of conservative safety analysis and flexibility in package selection, this NI PEIS assumes that commercial vehicles are used for target shipments. Under DOE Order 474.1, plutonium-238 would be in a safeguard category less than Categories I and II, which require the use of a safe, secure trailer. However, DOE Order Supplemental Directive AL 5610.14 directs the use of the Transportation Safeguards System for shipments of plutonium-238.

The SST/SGT is a specially designed component of an 18-wheel tractor-trailer vehicle. While 49 CFR Section 173.7(b) exempts SST/SGT shipments from DOT regulations, DOE operates and maintains these vehicles in a way that exceeds DOT requirements. Although details of vehicle enhancements and some operational aspects are classified, key characteristics of the SST/SGT system include the following:

- Enhanced structural characteristics and a highly-reliable tie-down system to protect cargo from impact
- Heightened thermal resistance to protect the cargo in case of fire (newer SST/SGT models)
- Established operational and emergency plans and procedures governing the shipment of nuclear materials
- Various deterrents to prevent unauthorized removal of cargo
- An armored tractor component that provides courier protection against attack and contains advanced communications equipment
- Specially designed escort vehicles containing advanced communications and additional couriers
- 24-hour-a-day real-time communications to monitor the location and status of all SST/SGT shipments via DOE's Security Communication system
- Couriers, who are armed Federal officers, receive rigorous specialized training and are closely monitored through DOE's Personnel Assurance Program
- Significantly more stringent maintenance standards than those for commercial transport equipment
- Conduct of periodic appraisals of the Transportation Safeguards System operations by the DOE Office of Defense Programs to ensure compliance with DOE orders and management directives, and continuous improvement in transportation and emergency management programs.

Loading and unloading of SST/SGTs at DOE sites is routinely done in accordance with site facility and Transportation Safeguards Division procedures. However, special attention is required at commercial facilities and military ports. The DOE SST/SGT operations team will direct and approve loading and securing of packages within SST/SGT vehicles and will be solely responsible for closing and securing SST/SGT vehicles and cargo areas prior to transport. DOE will take custody of packaged mixed oxide nuclear reactor fuel loaded on SST/SGT vehicles for transport at the military port and of the packaged highly enriched uranium or highly enriched uranium nuclear fuel at the commercial site. DOE will require that the commercial German and/or Scottish entities involved in shipping the material fully comply with the Certificate of Compliance for the package and applicable NRC and DOT regulations in preparing and offering packaged mixed oxide fuel for transportation, including proper shipping papers and nuclear material transfer forms. DOE anticipates that, if applicable, approved IAEA safeguard seals will be placed on packages in accordance with established protocols and procedures by the shippers, DOE, and other cognizant authorities prior to release of loaded packages for transport. IAEA safeguard seals may also be applied to transport vehicles.

Task interactions between Transportation Safeguards Division operations teams, the SST/SGT operations center, the shipping company, and military port operations and security personnel involved in loading, securing, and dispatching SST/SGT shipments will be conducted in accordance with the requirements of DOE Orders 5610.14, 5632.1C, and 474.1 and SST/SGT operations procedures. The military port and ship will provide necessary labor, loading areas and docks, and package-handling equipment that is necessary for loading mixed oxide transportation packages into SST/SGTs. Personnel involved in fuel-handling operations will be required to have a "need to know" and possess either appropriate NRC [per 73.50(c)(1)] or DOE Level 3 (per DOE M 474.1) access authorization. In dispatching shipments of mixed oxide fuel to FFTF, DOE's SST operations team and operations center will also coordinate with the security operations center at a DOE site. Estimated time of arrival, shipment, and material accountability information will be transmitted to designated persons at the FFTF in accordance with prearranged protocols. DOE anticipates the time necessary to prepare, load, secure, and dispatch SST/SGTs to be on the order of less than 1 day (per convoy).

DOE realizes that the use of SST/SGT vehicles complicates package handling. ORNL/TM-13427 (Ludwig 1997) provides the following general dimensions for an SST:

Gross vehicle weight rating	36,288 kilograms (80,000 pounds)
Maximum payload	6,169 kilograms (13,600 pounds)
Trailer overall length	18.3 meters (60 feet)
Trailer overall width	259 centimeters (102 inches)
Trailer overall height	410 meters (13 feet)
Trailer rear door width	179.1 to 215.9 centimeters (70.5 to 85 inches)
Trailer rear door height	229 centimeters (990 inches)
Trailer floor height above roadway	144 centimeters (56.5 inches)
Tractor trailer minimum turning radius	11.4 meters (37.5 feet)

SGT dimensions are similar. The payload and physical dimensions of the trailer will constrain the selection of a cask for the mixed oxide fuel and for plutonium-238 targets. Additionally, a gurney or similar device will be necessary to place the cask into the SST/SGT. The ship, port, or facility crane would place the cask on the gurney, and the gurney would load the cask into the SST/SGT. The cask would be tied down in accordance with normal SST/SGT operational procedures.

J.3.5 Ground Transportation Route Selection Process

According to DOE guidelines, radioactive material shipments must comply with both NRC and DOT regulatory requirements. NRC regulations cover the packaging and transport of neptunium, plutonium and waste, whereas DOT specifically regulates the carriers and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. The highway routing of nuclear material is systematically determined according to DOT regulation 49 CFR Part 397 for commercial shipments. Specific routes cannot be publicly identified in advance for DOE's Transportation Safeguards Division's shipments because they are classified to protect national security interests.

DOT routing regulations require that shipment of a highway route controlled quantity of radioactive material be transported over a preferred highway network, including interstate highways, with preference toward interstate system bypasses and beltways around cities and state-designated preferred routes. A state may designate a preferred route to replace or supplement the interstate highway system in accordance with DOT requirements (49 CFR Section 397.103).

Carriers of highway route-controlled quantities are required to use the preferred network unless they are moving from their origin to the nearest interstate highway or from the interstate highway to their destination, they are making necessary repair or rest stops, or emergency conditions render the interstate highway unsafe or impassable. The primary criterion for selecting the preferred route for a shipment is travel time. Preferred routing takes into consideration accident rate, transit time population density, activities, time of day, and day of the week.

The HIGHWAY computer code (Johnson et al. 1993) is used for selecting highway routes in the United States. The HIGHWAY database is a computerized road atlas that describes about 386,400 kilometers (240,000 miles) of roads. The Interstate System and all U.S. (U.S.-designated) highways are completely described in the database. Most of the principal state highways and many local and community roads are also identified. The code is updated periodically to reflect current road conditions and has been benchmarked against reported mileages and observations of commercial truck firms. Features in the HIGHWAY code allow the user to select routes that conform to DOT regulations. Additionally, the HIGHWAY code contains data on population densities along the routes. The distances and populations from the HIGHWAY code are part of the information used for the transportation impact analysis in this NI PEIS.

J.3.6 Shipment of SNR–300 Fuel

The SNR–300 reactor, located at Kalkar in the northwest of Germany, was designed and constructed as a 327 megawatt (electric) fast breeder power reactor. However, in the 1980s, startup and operation fell into disfavor and the German government decided not to operate the SNR–300 reactor.

In parallel with the construction of the SNR–300 reactor, and in anticipation of its ultimate operation, approximately 205 mixed oxide fuel assemblies were fabricated in Europe. This unused inventory of reactor fuel is now stored at Dounreay, Scotland, and has raised international concerns over its possible proliferation as weapons-usable nuclear material. Currently, there is interest in having these surplus fuel assemblies transferred to the United States for disposition to reduce and eventually eliminate the proliferation potential of this material.

The SNR–300 fuel is very similar in both composition and construction to the fuel used in the FFTF at Hanford. The SNR–300 fuel assemblies, if reconfigured for the FFTF, could make about 150 to 160 FFTF assemblies. This could supply two FFTF core loads for approximately 15 years of FFTF operation at 100 megawatts.

Conversion of SNR–300 fuel into FFTF fuel has been previously studied. Reconfiguration to FFTF fuel would include disassembly of SNR–300 fuel assemblies, removal of fuel pin end caps in a glovebox, addition of tag gas and retainer, re-closing fuel pins (weld) and leak testing, addition of wire wrap to fuel pins, inverting the pins and reinsertion into an FFTF fuel assembly duct, completion of FFTF bundle assembly, and quality assurance verification. This would be done in Europe prior to packaging the fuel for shipment to the United States.

The risk of possible use of nuclear material for non-peaceful purposes underlines the need for its special protection. Therefore, effective systems are required to protect this material from theft, sabotage or other malicious acts. The elaborate measures to be taken to ensure the safety and security of transatlantic mixed oxide shipments are provided in:

- *Convention on the Physical Protection of Nuclear Material*, IAEA publication INFCIRC 274,
- *Recommendations on the Physical Protection of Nuclear Material*, IAEA publication INFCIRC 225,

- *Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium, and High-Level Radioactive Wastes in Flasks on Board Ships* (IMO 1993), and
- DOE orders and 10 CFR Part 73.

J.3.6.1 Port Selection

Physically, any seaport could receive mixed oxide fuel. Legally, the mixed oxide fuel could be brought into many commercial and military ports. In the *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (*Foreign Research Reactor Spent Nuclear Fuel EIS*) (DOE 1996), DOE developed and implemented a systematic process for selecting ports of entry for spent nuclear fuel. Information needed to evaluate ports and port activities, and the potential environmental impacts (incident-free and accidents) associated with the receipt of foreign research reactor spent nuclear fuel from vessels were collected and evaluated. In the *Foreign Research Reactor Spent Nuclear Fuel EIS*, 153 commercial ports and 13 military ports were evaluated (DOE 1996).

The criteria used for screening ports in the *Foreign Research Reactor Spent Nuclear Fuel EIS* were 1) appropriate port experience, 2) safe port transit to open ocean; 3) appropriate port facilities for safe receipt, handling and transshipment; 4) ready intermodal access; and 5) low human population of the ports and along transportation routes (DOE 1996). These same criteria can be used to identify ports for receiving mixed oxide fuel from Europe. **Table J–1** shows the military ports (the analysis of Hampton Roads, Virginia, covers several military and commercial facilities in that area) considered in the *Foreign Research Reactor Spent Nuclear Fuel EIS*, the distance to Hanford and the number of persons along the route. The following discusses the application of these criteria for mixed oxide fuel.

Table J–1 Overland Distances from Military Ports to Hanford and Affected Persons Along the Routes

Port	Distance (kilometers [miles])	Number of Affected Persons
Eastern ports		
Charleston Naval Weapons Station, South Carolina	4,677 (2,894)	609,000
Military Ocean Terminal Sunny Point, North Carolina	5,157 (3,194)	679,000
Mayport, Florida	4,754 (2,964)	624,000
Kings Bay, Georgia	4,685 (2,926)	555,000
Pensacola, Florida	4,430 (2,767)	549,000
Yorktown, Virginia	4,717 (2,946)	569,000
Hampton Roads, Virginia	4,748 (2,949)	694,000
Western ports		
Military Ocean Terminal Bay Area, California	1,531 (951)	263,000
Bremerton, Washington	451 (282)	143,000
Everett, Washington	397 (248)	135,000
Port Hueneme, California	2,030 (1268)	386,000
Port Townsend, Washington	666 (416)	159,000

Note: All except the Charleston Naval Weapons Station are from DOE 1996. Charleston Naval Weapons Station is from Table J–2.

Criterion 1, Appropriate Port Experience. DOE believes that all military ports could establish a secure area for loading mixed oxide fuel packages into SST/SGTs. Therefore, any of the named ports could safely and securely handle these packages. Charleston Naval Weapons Station has been the primary port for receipt of foreign research reactor spent nuclear fuel for the last 5 years. Dozens of casks have been safely and securely received and transported to DOE facilities. Therefore, it is clearly the most experienced port. Military Ocean Terminal Sunny Point received two foreign research reactor spent nuclear fuel casks in 1994, so it has some experience. Military Ocean Terminal Bay Area has received several packages of foreign research reactor spent nuclear fuel from training, research, and isotope reactors (TRIGA reactors built by General Atomics) and shipped these packages to INEEL. The port at Hampton Roads, Virginia, has experience handling spent fuel casks and has recent experience handling Russian plutonium-238 for DOE (DOE 1993).

Criterion 2, Safe Port Transit. All of the ports listed have demonstrated safe port transit based on their continuous and routine usage by seagoing military vessels. DOE could choose to provide enhanced safety and security in the immediate vicinity of ports using necessary harbor patrol, Coast Guard and Naval assets. However, western ports require transit through the Panama Canal. While traveling through the Panama Canal, the ship would be in Panamanian waters, where DOE could not directly request assistance from other assets.

Criterion 3, Appropriate Port Facilities. The *Foreign Research Reactor Spent Nuclear Fuel EIS* evaluated Charleston Naval Weapons Station, Military Ocean Terminal Sunny Point and Military Ocean Terminal Bay Area in detail and determined that they had appropriate facilities. Essentially all working seaports have port cranes capable of lifting mixed oxide casks from the ships. At least a 30-metric ton (33-ton) capacity crane would be adequate. For seaports without a port crane, portable cranes are available in most areas. Purpose-built ships are moderate sized oceangoing vessels, and all of the identified ports have berthing facilities with adequate water depth and length to allow safe access. While Charleston Naval Weapons Station, Military Ocean Terminal Sunny Point and Military Ocean Terminal Bay Area have actually used their facilities and procedures to unload Type B casks for DOE, DOE considers the other military ports to have appropriate facilities and could establish procedures for the security necessary around the ship carrying the mixed oxide fuel.

Criterion 4, Ready Intermodal Access. Access to other modes of transportation, such as rail and barge routes, was relevant for the *Foreign Research Reactor Spent Nuclear Fuel EIS* but are not relevant to this NI PEIS since the mixed oxide fuel will travel over roads in SST/SGTs.

Criterion 5, Low Human Population. The distance to Hanford and the population along the routes are similar for each of the eastern ports. All are within 15 percent of the average distance and number of affected persons. The western ports vary significantly, but are all lower than the eastern ports. The *Foreign Research Reactor Spent Nuclear Fuel EIS* did not calculate the populations around all of the military ports listed in Table J–1. However, it conducted detailed risk analyses for delivery of foreign research reactor spent nuclear fuel to ports located near heavily populated metropolitan areas such as New York, New York (port of Elizabeth, New Jersey) and Los Angeles, California (port of Long Beach, California). The accident risk for direct shipment to these ports is less than 1×10^{-5} latent cancer fatality per shipment. The risk of foreign research reactor spent nuclear fuel material bounds the risk of fresh mixed oxide fuel because of the fission products in spent nuclear fuel. The population of the New York and Los Angeles metropolitan areas bounds the population in the area of any military ports. Therefore, all of the ports listed meet the low human population criteria for the area around the port, and the populations along the routes are as shown in Table J–1.

The voyage distance from Europe to the eastern United States is about 4,000 nautical miles, and the distance to the western United States is about 8,000 nautical miles, through the Panama Canal. There are no known restrictions for passing mixed oxide fuel through the Panama Canal. Using the *Foreign Research Reactor Spent Nuclear Fuel EIS* methodology, the voyage duration for the east coast is about 12 days, about 24 days for the west coast. Traveling to the west coast along a route south of South America or Africa is more than double the distance of the route through the Panama Canal and considered to be prohibitive for practical reasons.

DOE is currently in negotiation with Germany on the details for receiving this fuel. The Germans would be responsible for the fuel until it is delivered to DOE at a U.S. port. The Germans may not be willing to ship the fuel to a western port because of the cost associated with the longer voyage, and possible safety and security issues associated with using the Panama Canal. On the open seas, purpose-built ships are considered to be safe and secure based on their design, the distance from threats, and their constant communication with authorities. However, they are more vulnerable in the constrained waters of the Panama Canal, since these waters are not controlled by German or American authorities.

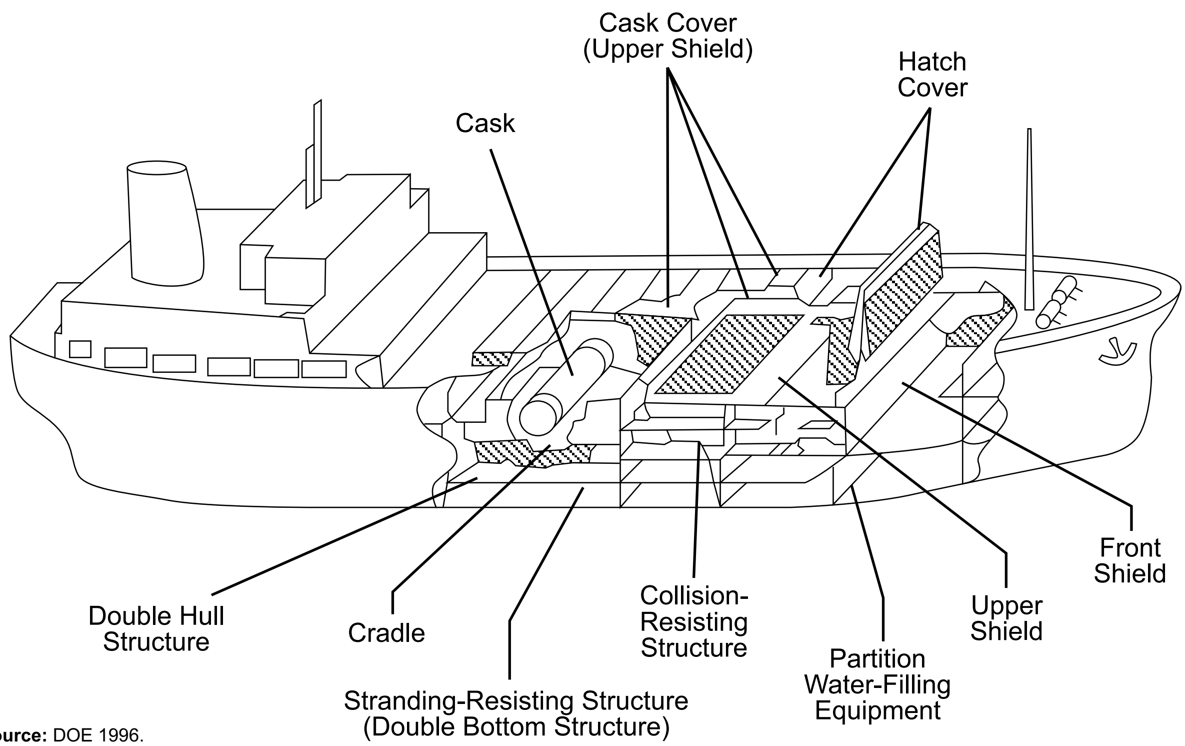
In the *Foreign Research Reactor Spent Nuclear Fuel EIS* Record of Decision, DOE decided to use military ports to take advantage of their characteristics to increase the safety and security of the spent fuel transportation process. DOE concluded that the use of military ports provides additional confidence in the safety of shipments due to the increased security. This could also require much of the spent nuclear fuel to be shipped by chartered ships because commercial ships do not schedule stops at military ports. Since the security issues are far greater for fresh mixed oxide fuel than for spent nuclear fuel because of the potential for proliferation, DOE would use a military port to bring the SNR–300 into the country. This conclusion is consistent with Criterion 3, Appropriate Port Facilities. The impact analysis is described in Section J.6.2. The Charleston Naval Weapons Station is used for the purpose of impact analysis.

J.3.6.2 Purpose-Built Vessels

As used here, purpose-built vessels, are those vessels specifically designed to transport spent nuclear fuel casks (**Figure J–7**). These vessels are not used for the transport of any other cargo and they operate as dedicated vessels. Casks are loaded directly into the holds of the vessel because the cargo compartments contain the hardware needed to mate with the tiedown fixtures of the cask. If the vessel has no crane, dockside cranes are used for loading and unloading. The cargo compartments are typically intended to handle a specific cask; other casks cannot be used without modification to the tiedown mechanisms.

At present, purpose-built vessels are operated by Pacific Nuclear Transport Services of Japan, by the Swedish Nuclear Fuel and Waste Management Company, and by British Nuclear Fuels, Limited. They are used to move spent nuclear fuel from operating nuclear power plants to spent nuclear fuel processing facilities operated by COGEMA and British Nuclear Fuels, Limited; or, in the case of Sweden, to the repository in Forsmark. Since 1998, they have been used to transport spent nuclear fuel from foreign research reactors to the Charleston Naval Weapons Station. There are no U.S.-owned purpose-built vessels for spent nuclear fuel transport.

Pacific Nuclear Transport Services operates a fleet of purpose-built ships that carried mixed oxide fuel from Europe to Japan in the summer of 1999 (COGEMA, BNFL, ORC 2000). Pacific Nuclear Transport Services' ships are representative of, but not identical to the other fleets. All ships in the fleet are certified to INF3—the highest safety category of the International Maritime Organization for nuclear voyages. The ships have been designed and built specifically to carry these nuclear materials. They employ a range of safety features far in excess of those found on conventional cargo vessels. The ships are constructed with double hulls, effectively making them able to withstand a severe collision with a much larger vessel without penetrating the inner hull. Each ship has two sets of navigation, communications, cargo monitoring, electrical and cooling systems, so there is always a back-up in the event of failure or damage. The navigation system includes automatic radar plotting and collision avoidance equipment. This redundancy extends to the ship's propulsion system. Every part of the Pacific Nuclear Transport Services' ships is covered by a fire detection system. And every vessel has sophisticated firefighting equipment on board. In the highly unlikely event of fire, a ship's hold, engine room or any other on-board space, may be flooded with fire-suppressant gases.



Source: DOE 1996.

Figure J–7 Purpose-Built Vessel

Individual holds can even be deliberately flooded, and if all the holds were flooded in this way, the ship would still remain afloat. The ships carry the most modern satellite and navigation, weather routing and tracking equipment, enabling them to automatically transmit their position. While at sea, each ship's crew can maintain permanent communication with a report center that is operated 24 hours a day (COGEMA, BNFL, ORC 2000).

J.4 METHODS FOR CALCULATING TRANSPORTATION RISKS

The overland transportation risk assessment method is summarized in **Figure J–8**. After this NI PEIS alternatives were identified and the goals of the shipping campaign were understood, data were collected on material characteristics and accident parameters. Accident parameters were largely based on NRC studies of transportation accidents undertaken for NUREG-0170, the *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977) and the Modal Study (NUREG/CR-4829) (Fischer et al. 1987).

Representative routes that may be used for the shipments were selected for risk assessment purposes using the HIGHWAY code. They do not necessarily represent the actual routes that would be used to transport nuclear materials. Specific routes cannot be identified in advance because the routes cannot be finalized until they have been reviewed and approved by the NRC. The selection of the actual route would be responsive to environmental and other conditions that would be in effect or could be predicted at the time of shipment. Such conditions could include adverse weather conditions, road conditions, bridge closures, and local traffic problems. For security reasons, details about a route would not be publicized before the shipment.

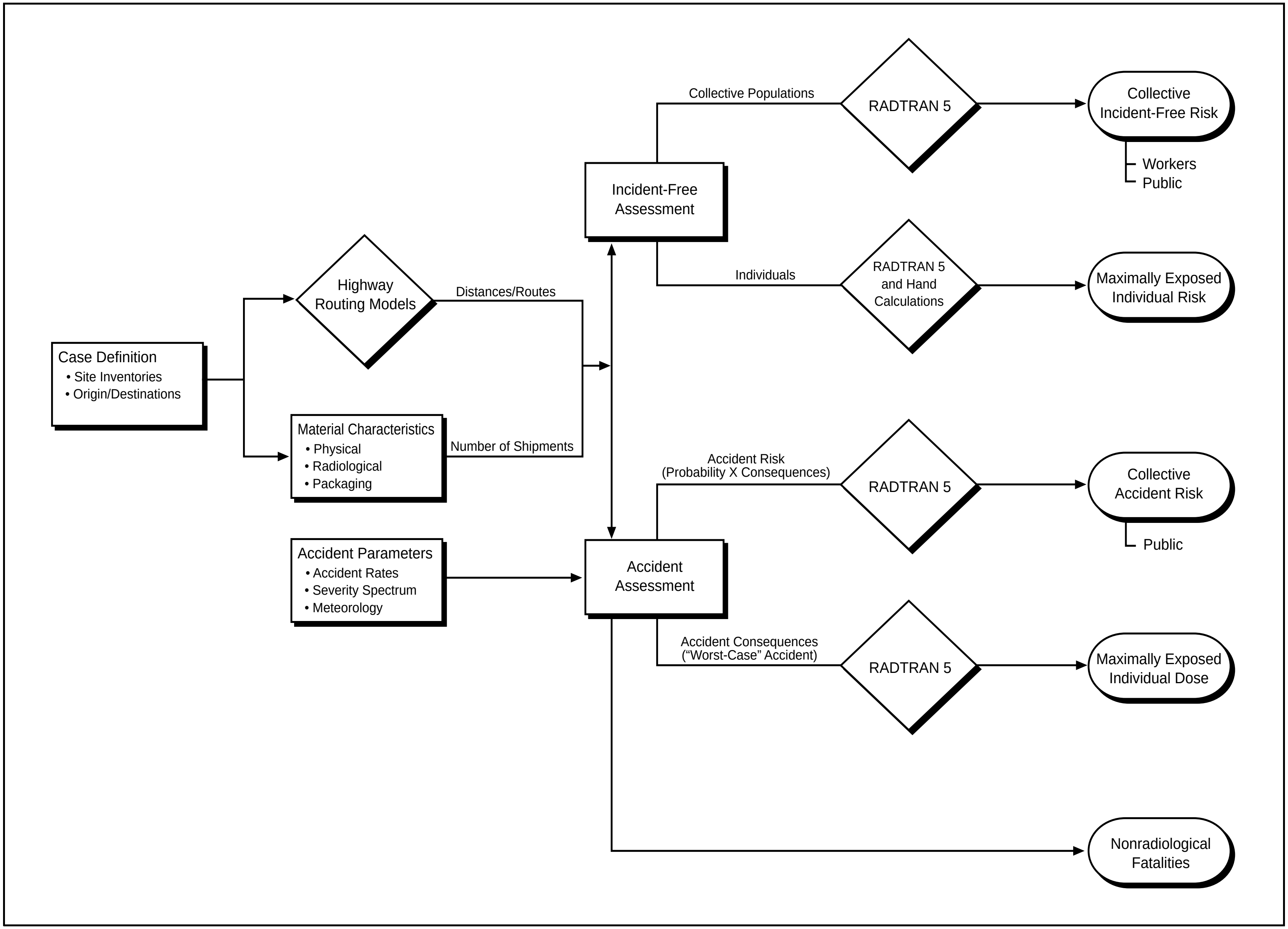


Figure J–8 Overland Transportation Risk Assessment

Air transport of shipping casks was modeled on procedures for radiopharmaceutical suppliers using commercial air transport at the Tri-Cities Airport in Pasco, Washington. As a bounding assumption, air transport of shipping casks is assumed to be on commercial passenger flights. The shipping cask would be unloaded from their truck shipments and shipped to the destination airport with a stopover and plane change, for the purpose of impact analysis, in Salt Lake City, Utah.

The first analytic step in the transportation analysis was to determine the incident-free and accident risk factors on a per-shipment basis. Risk factors, as with any risk estimate, are the product of the probability of exposure and the magnitude of the exposure. Accident risk factors were calculated for radiological and nonradiological traffic accidents. The probabilities, which are much lower than one, and the magnitudes of exposure were multiplied, yielding very low risk numbers. Incident-free risk factors were calculated for crew and public exposure to radiation emanating from the shipping container (cask) and public exposure to the chemical toxicity of the truck exhaust. The probability of incident-free exposure is unity (one).

For each alternative, risks were assessed for both incident-free transportation and accident conditions. For the incident-free assessment, risks are calculated for both collective populations of potentially exposed individuals and for maximally exposed individuals. Handling doses are included in the transportation risk for airport and seaport handling. Truck unloading at DOE sites is included in facility dose estimates. The accident assessment consists of two components: (1) a probabilistic accident risk assessment that considers the probabilities and consequences of a range of possible transportation accident environments, including low-probability accidents that have high consequences, and (2) an accident consequence assessment that considers only the consequences of maximum foreseeable transportation accidents.

As a practical matter, the maximum foreseeable transportation accident is defined as an accident with a frequency of greater than 1×10^{-7} per year (once in 10 million years). This hypothetical accident is well beyond the "design basis" of a transportation cask. The "design basis" of a transportation cask is to survive the tests shown in Figure J–1 without releasing its contents. The risk of accidents that are less likely than the maximum foreseeable accident are included in the analysis, but specific accident sequences and consequences are not analyzed. It would not be practical to analyze all potential accident forces that could affect a transportation cask because there are such a large number of potential scenarios and locations.

The RADTRAN 5 computer code (Neuhauser and Kanipe 2000) is used for incident-free and accident risk assessments to estimate the impacts on population. RADTRAN 5 was developed by Sandia National Laboratories to calculate population risks associated with the transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge. RADTRAN 5 was used to calculate the doses to the maximally exposed individuals.

The RADTRAN 5 population risk calculations take into account both the consequences and probabilities of potential exposure events. The RADTRAN 5 code consequence analyses include cloud shine, ground shine, inhalation, and resuspension exposures. The collective population risk is a measure of the total radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk is used as the primary means of comparing the various alternatives.

J.5 ALTERNATIVES, PARAMETERS, AND ASSUMPTIONS

J.5.1 Description of Alternatives

Five alternatives with numerous options and a No Action Alternative with options have been identified for this NI PEIS. **Table J–2** depicts these alternatives and the following describes them from a transportation perspective.

J.5.1.1 No Action Alternative

Option 1. Plutonium-238, needed in power systems for future space missions, would continue to be purchased from Russia. The transportation analysis performed in the *Environmental Assessment of the Import of Russian Plutonium-238* (DOE 1993) would be expanded to cover the transportation from Russia, through the ports of entry, and to the Los Alamos National Laboratory (LANL) site for the time period covered by this NI PEIS, as described in Chapter 4. Medical, industrial, and research and development isotope production would continue as per the current conditions. Neptunium-237 would not be converted to oxide or shipped.

Options 2, 3, and 4. These options are like the No Action Alternative, Option 1 in all respects except for the disposition of the neptunium-237. The neptunium-237 would be converted to oxide and transported from SRS to a storage site at ORR, INEEL, or Hanford. The neptunium transportation would be the only transportation leg quantitatively analyzed in this NI PEIS.

J.5.1.2 Alternative 1—Restart FFTF

FFTF Production (Options 1 through 3). FFTF at Hanford would be used to produce up to 5 kilograms (11 pounds) per year of plutonium-238 and medical, industrial, and research and development isotopes. When the mixed oxide fuel already at Hanford is depleted, FFTF would use SNR–300 mixed oxide fuel imported from Europe, and after 21 years of operation, would switch to highly enriched uranium fuel. For the purpose of analysis, it is assumed that the mixed oxide fuel enters the United States at the Charleston Naval Weapons Station and is shipped in SSTs to FFTF. The analysis includes shipment of a single mixed oxide fuel assembly for testing in the FFTF reactor and the shipping campaign during mixed oxide fuel operations. The highly enriched uranium fuel would be fabricated at a commercial fuel fabrication facility located in the eastern United States. Medical and industrial isotope target fabrication and processing would occur at Hanford, using purified materials from ORR, and the products would be shipped to commercial vendors as described in Section J.5.3. Plutonium-238 production would require the transportation of neptunium-237 from SRS to a target fabrication facility at ORR, INEEL, or Hanford; transportation of unirradiated targets from the fabrication facility to Hanford; transportation of irradiated targets from Hanford to a target processing facility at the same locations as the fabrication facility; and transportation of plutonium-238 from the fabrication facility to LANL.

FFTF Production (Options 4 through 6). Options 4 through 6 are similar to Options 1 through 3, with differences in timing and fuel source for FFTF. When the mixed oxide fuel already at Hanford is depleted, FFTF would immediately switch to highly enriched uranium fuel as described for Options 1 through 3.

J.5.1.3 Alternative 2—Use Existing Operational Facilities

One-Reactor Production (Options 1 through 6). The ATR at INEEL or a CLWR would be used to produce up to 5 kilograms (11 pounds) per year of plutonium-238. Therefore, production would require the transportation of neptunium-237 from SRS to a target fabrication facility at ORR, INEEL, or Hanford;

Table J–2 NI PEIS Alternatives and Options

Alternative Option Number	Irradiation Options						Storage, Target Fabrication, and Processing Options		
	FFTF (Hanford)	ATR (INEEL)	HFIR (ORR)	CLWR	Accelerator	New Reactor	REDC (ORR)	FDPF (INEEL)	FMEF[a] (Hanford)
No Action Alternative									
Option 1									
Option 2							●		
Option 3								●	
Option 4									●
Alternative 1—Restart FFTF									
Option 1	●						●		
Option 2	●							●	
Option 3	●								●
Option 4	●						●		
Option 5	●							●	
Option 6	●								●
Alternative 2—Use Existing Operational Facilities									
Option 1		●					●		
Option 2		●						●	
Option 3		●							●
Option 4				●			●		
Option 5				●				●	
Option 6				●					●
Option 7		●	●				●		
Option 8		●	●					●	
Option 9		●	●						●
Alternative 3—Construct New Accelerator(s)									
Option 1					●		●		
Option 2					●			●	
Option 3					●				●
Alternative 4—Construct New Research Reactor									
Option 1						●	●		
Option 2						●		●	
Option 3						●			●
Alternative 5—FFTF Deactivation (with No New Missions)									

a. FMEF is being considered along with several other facilities. See Chapter 2 for details.
Key: ATR, Advanced Test Reactor; CLWR, commercial light water reactor, no defined location; FDPF, Fluorinel Dissolution Process Facility; FFTF, Fast Flux Test Facility, Hanford Site; FMEF, Fuels and Materials Examination Facility, 400 Area, Hanford Site; HFIR, High Flux Isotope Reactor; INEEL, Idaho National Engineering and Environmental Laboratory; INTEC, Idaho Nuclear Technology and Engineering Center; ORNL, Oak Ridge National Laboratory; ORR, Oak Ridge Reservation; REDC, Radiochemical Engineering Development Center, TRA, Test Reactor Area.

transportation of unirradiated targets from the fabrication facility to INEEL or a CLWR; transportation of irradiated targets from INEEL or a CLWR to a target processing facility at the same location as the fabrication facility; and transportation of plutonium-238 from the fabrication facility to LANL. Medical, industrial, and research and development isotope production would continue per current conditions.

Two-Reactor Production (Options 7, 8, and 9). The ATR at INEEL and HFIR at ORR would be used to produce plutonium-238. HFIR could only produce between 1 and 2 kilograms (2.2 and 4.4 pounds) of plutonium-238 per year. Therefore, between 3 and 4 kilograms (6.6 and 8.8 pounds) per year would be produced at ATR. Production would require the transportation of neptunium-237 from SRS to a target fabrication facility at ORR, INEEL, or Hanford; transportation of unirradiated targets from the fabrication facility to ORR and INEEL; transportation of irradiated targets from ORR and INEEL to a target processing facility at the same location as the fabrication facility; and transportation of plutonium-238 from the fabrication facility to LANL. It is assumed that production rates at ATR and HFIR would require the maximum amount of transportation. For example, in Option 7 (target fabrication and processing at ORR), it is assumed that HFIR produces its minimum rate of 1 kilogram (2.2 pounds) per year of plutonium-238, which maximizes the transportation to INEEL. Medical, industrial, and research and development isotope production would continue per the current conditions.

J.5.1.4 Alternative 3—Construct New Accelerator(s)

One or two new accelerators at a generic DOE site would be used to produce up to 5 kilograms (11 pounds) per year of plutonium-238 and medical and industrial isotopes, as well as conducting nuclear research and development. The accelerator(s) would be on a DOE site to be identified later. Shipping distances, route characteristics, and material inventories are assumed to be the same as those modeled in HNF-1844 (Lavender and Nielsen 1997). Medical and industrial isotope target fabrication and processing would occur on the accelerator site, and the products would be shipped to commercial vendors. Plutonium-238 production would require the transportation of neptunium-237 from SRS to a target fabrication facility at ORR, INEEL, or Hanford; transportation of unirradiated targets from the fabrication facility to the accelerator(s); transportation of irradiated targets from the accelerator(s) to a target processing facility at the same locations as the fabrication facility; and transportation of plutonium-238 from the fabrication facility to LANL.

J.5.1.5 Alternative 4—Construct New Research Reactor

A new research reactor at a generic DOE site would be used to produce up to 5 kilograms (11 pounds) per year of plutonium-238 and medical and industrial isotopes, as well as conducting nuclear research and development. The reactor would be on a DOE site to be identified later. Shipping distances, route characteristics, and material inventories are assumed to be the same as those modeled in HNF-1844 (Lavender and Nielsen 1997). Medical and industrial isotope target fabrication and processing would occur on the reactor site, and the products would be shipped to commercial vendors. Plutonium-238 production would require the transportation of neptunium-237 from SRS to a target fabrication facility at ORR, INEEL, or Hanford; transportation of unirradiated targets from the fabrication facility to the reactor; transportation of irradiated targets from the reactor to a target processing facility at the same location as the fabrication facility; and transportation of plutonium-238 from the fabrication facility to LANL.

J.5.1.6 Permanently Deactivate FFTF (with No New Missions)

No offsite transportation of radioactive material would occur as a result of selecting this alternative. The sodium coolant would be removed from FFTF and processed at Hanford. Any transportation impacts would be negligible compared with the impacts of other alternatives. Medical, industrial, and research and development isotope production would continue per the current conditions.

J.5.2 Material Inventory

The amount of material that must be shipped is determined from the basic mission requirement to remove the neptunium-237 from SRS to a new storage facility to produce plutonium-238. The amount of neptunium-237 currently stored at SRS is classified, so the total storage volume of REDC is used as a surrogate to bound the amount of neptunium-237. Therefore, the neptunium-237 transportation impacts to each facility are conservative. The stated mission is to produce 5 kilograms (11 pounds) of plutonium-238 per year for 35 years. **Table J–3** summarizes the masses of material and the number of shipments required to implement the various alternatives, and can be used in conjunction with Table J–1 to determine the origins and destinations of the shipments for the various alternatives. The material masses listed are those of heavy metal. Neptunium and plutonium shipments also contain small amounts of radioactive decay products, and irradiated targets contain fission products.

DOE estimates that about 50 kilograms of neptunium-237 will have to be exposed to reactor flux to make 5 kilograms of plutonium-238. This neptunium-237 would be shipped in about 9 shipments per year, each carrying about 6 kilograms of neptunium in the unirradiated targets. The targets would be returned to the fabrication and processing facility with about 5 kilograms of neptunium-237 and less than a kilogram of plutonium. Again, about 9 shipments per year would be needed to return the irradiated targets. For options in which some or all of the irradiation is done at the same DOE site as the fabrication and processing, less transportation is required. These transportation assumptions are used for irradiation at FFTF (Alternative 1) existing reactors (Alternative 2), the new accelerators (Alternative 3), and the new research reactor (Alternative 4).

The highly enriched uranium transportation assumptions are based on the assumption of 16 fuel assemblies per year made from 35 percent enriched uranium (Nielsen 1999). The fuel assemblies would contain about 27 kilograms of heavy metal. The SNR–300 mixed oxide fuel transportation requirements come from information provided by SBK of Germany (Hiller 2000).

These assumptions are considered preliminary. Since they provide for conservative amounts of material shipped and numbers of shipments, they are considered to be adequate for impact analysis. No specific estimates of transportation requirements for other research and development isotopes have been included. However, DOE believes that they are small compared to the transportation requirements assumed for medical isotopes. If large research and development projects are scheduled in the future, they would displace some of the medical isotope or plutonium-238 production and their transportation impacts would be similar or less.

Table J–3 Summary of Material Shipments

Material	Container	Applicable Alternatives	SST/ SGT[a]	Number of Trips	Amount of Heavy Metal per Package	Packages per Shipment	Total Heavy Metal Shipped
Neptunium-237	9975[b]	NA-2 through NA-4, 2, 3, & 4	Yes	98	3 kilograms of neptunium	14	1,960 kilograms
Unirradiated targets (neptunium-237)	To be determined; similar to GE–2000	1, 2-1 through 2-6, & 4	No	315	6 kilograms of neptunium	1	1,750 kilograms of neptunium
		2-7		252			1,400 kilograms of neptunium
		2-8 & 2-9		126			700 kilograms of neptunium
	To be determined	3		105	500 kilograms of uranium 72 kilograms of neptunium	1	52,500 kilograms of uranium 7,560 kilograms of neptunium
Irradiated targets (plutonium-238)	To be determined; similar to GE–2000	1, 2-1 through 2-6, & 4	No	315	0.6 kilograms of plutonium 5 kilograms of neptunium	1	175 kilograms of plutonium 1, 500 kilograms of neptunium[c]
		2-7		252			140 kilograms of plutonium 1,200 kilograms of neptunium[c]
		2-8 & 2-9		126			70 kilograms of plutonium 600 kilograms of neptunium[c]
	To be determined	3		105	500 kilograms of uranium 70 kilograms of neptunium 2 kilograms of plutonium	1	52,500 kilograms of uranium 7,350 kilograms of neptunium 210 kilograms of plutonium
Plutonium-238	5320	1, 2, 3, & 4	Yes	35	0.35 kilograms of plutonium	15	175 kilograms of plutonium
Highly enriched uranium	DT-22 or DC-1	1-1 through 1-3	Yes	5	10 kilograms of highly enriched uranium	12	520 kilograms of highly enriched uranium
		1-4 through 1-6		9			1,080 kilograms of highly enriched uranium
Highly enriched uranium fuel	To be determined	1-1 through 1-3	Yes	56	26.5 kilograms of uranium	4	1,500 kilograms of uranium
		1-4 through 1-6		116			3,100 kilograms of uranium
Fresh SNR–300 mixed oxide fuel	GB/1356 or SNR-300	1-1 through 1-3	Yes	79	70 kilograms of plutonium, uranium, and americium	1	5,500 kilograms of plutonium, uranium, and americium
Irradiated targets (medical isotopes)	T-2	1, 3, & 4	No	8,610	Various	1	NA
Separated isotopes	To be determined	1,3, & 4	No	8,610	Various	1	NA

a. For purposes of analysis.
b. Either a redesigned 9975 or suitable replacement.
c. Much of the neptunium-237 is recycled into new targets during fabrication.

Note: 1 kilogram = 2.2 pounds.

Key: NA, not applicable; SST/SGT, safe, secure trailer/SafeGuards Transport.

J.5.3 Transportation of Medical Isotopes

DOE isotope program sales projections are made in the context of a worldwide market for radioactive isotopes. Isotope programs market share is a small fraction of the total, but is very significant for some products, and is particularly important for a large number of isotopes that are used in relatively small quantities for research. There is uncertainty in future growth trends, and recent studies have indicated a large potential for growth if promising research developments in the medical use of radioisotopes can be brought to commercialization. DOE's production rate could increase significantly as world demand changes.

Through the duration of the period covered by this NI PEIS, the transportation impacts of the current DOE isotope programs are and would remain very low compared to the proposed new missions analyzed in this NI PEIS. These isotopes are being produced at reactor and accelerator facilities throughout the country. Selection of Alternative 1, 3, or 4 would significantly increase the production capabilities with a corresponding increase in transportation impacts. Selection of the No Action Alternative or Alternative 2 would not increase production capabilities, nor would their selection significantly affect the baseline production rate. The transportation impacts from isotopes currently produced by DOE are small compared with the impacts of NI PEIS alternatives and are neglected for the purpose of transportation risk analysis. The following describes the transportation analyzed in this NI PEIS. The isotopes produced and transported are listed in Appendix C. Over 8,000 shipments, each with two truck and one aircraft leg, would be required to deliver these isotopes to commercial vendors. The transportation impacts of these representative isotopes are expected to bound the impacts of transportation associated with unspecified future research and development activities.

The transportation evaluation addressed the shipment of enriched target materials from Oak Ridge National Laboratory (ORNL) to Hanford for target fabrication, shipping the fabricated targets to FFTF, shipping the irradiated targets from FFTF to RPL for target processing, and shipping isotope products to commercial pharmaceutical distributors. HNF-1844 (Lavender and Nielsen 1997) analyzed distributors in Boston, Massachusetts; Chicago, Illinois; and St. Louis, Missouri. Only the results of shipping the isotopes to Boston are shown in this document to ensure that the risk analysis is bounding. The transportation impacts of medical isotopes were analyzed for FFTF and are considered to be the best estimate for FFTF or the hypothetical accelerator or research reactor. The impact analysis is bounding for the accelerator or reactor because either would be located on a major DOE site. The following paragraphs describe the material transportation for production at FFTF, with onsite target fabrication and processing, as analyzed in HNF-1844.

With the exception of the production of actinium-227, thorium-228, and thorium-229, this evaluation assumes that the same transportation scenario, from the target material supplier to the pharmaceutical distributor, is applicable to each isotope. That is, target materials are shipped from ORNL to PNNL, fabrication targets are shipped from PNNL to FFTF, irradiated targets are shipped from FFTF to PNNL, and the separated isotopes are shipped from PNNL to the three isotope distributors. Actinium-227, thorium-228, and thorium-229 are produced by irradiating a radium-226 target. Sufficient quantities of radium-226 would be stored at the target fabrication facility; there fore radium-226 target material is not shipped from ORNL to PNNL. The rest of the transport scenario from the target fabrication facility to the pharmaceutical distributor is the same as for other isotopes.

The target materials (with the exception of radium-226) required to produce the medical isotopes are assumed to be obtained from ORNL. The target materials would be shipped on an as-needed basis from ORNL to PNNL for target fabrication. Target fabrication is assumed to occur in the 300 Area at Hanford. For this analysis, it is assumed that target material would be shipped by truck one at a time from ORNL to PNNL. This is a bounding assumption that maximizes the number of shipments, because the trucks are capable of transporting loads containing multiple types of target materials. All of the target materials receive from ORNL are nonradioactive.

The target materials would be fabricated into specially-designed targets for irradiation at FFTF. The fabricated targets would be shipped by truck from RPL/306–E to FFTF. As with the target materials shipments, it was assumed that only one unirradiated target would be shipped at a time to FFTF. Following irradiation in FFTF, the irradiated targets would be shipped to RPL for required processing. Irradiated targets were assumed to be shipped by truck one at a time from FFTF.

Following required processing and packaging, an isotope product would be shipped by truck from RPL to the Tri-Cities Airport located in Pasco, Washington. From the Tri-Cities Airport, the isotopes are transported by air, using commercial passenger flights, to an intermediate airport or hub (i.e., Salt Lake City, Utah). At Salt Lake City, the isotopes are transferred to another airplane for transport to the airport nearest the pharmaceutical distributor in Chicago, Illinois (Amersham Mediphysics), Boston, Massachusetts (Dupont-Merck), and St. Louis, Missouri (Mallinckrodt). The isotope product is transported from the destination airport to the pharmaceutical distributor by truck, using public roadways. Shipments of waste (i.e., liquid processing waste and solid waste, including spent target hulls and miscellaneous wastes), would go to the 200 East and West Areas for subsequent storage and disposal (Lavender and Nielsen 1997).

J.5.4 Representative Routes

Representative overland truck routes were selected for the shipments to ORR, INEEL, Hanford, and SRS. The routes were selected consistent with current routing practices and all applicable routing regulations and guidelines (40 CFR Section 397.103). However, the routes were determined for risk assessment purposes. They do not necessarily represent the actual routes that would be used to transport materials in the future. Specific routes cannot be identified in advance. The planning process for actual shipments may identify similar routes, which would have similar public risks, but could be determined to be preferable. The representative truck routes are shown in **Figure J–9**.

Route characteristics that are important to the radiological risk assessment include the total shipment distance and the population distribution along the route. The specific route selected determines both the total potentially exposed population and the expected frequency of transportation-related accidents. Route characteristics are summarized in **Table J–4**. The population densities along each route are derived from 1990 data from the U.S. Bureau of the Census (DOC 1992). Rural, suburban, and urban areas are characterized according to the following breakdown: rural population densities range from 0 to 54 persons per square kilometer (0 to 139 person per square mile); the suburban range is from 55 to 1,284 persons per square kilometer (140 to 3,326 persons per square mile); and the urban range includes all population densities greater than 1,284 persons per square kilometer (3,326 persons per square mile). The exposed population, for the purpose of route characterization and incident-free dose calculation, includes all persons living within 800 meters (0.5 mile) of each side of the road.

Alternative 2, Options 4, 5, and 6 include irradiation of the neptunium targets at a CLWR. Determining which CLWR will actually provide the irradiation services is beyond the scope of this NI PEIS. For the purpose of impact analysis, a distance and population distribution that bounds all CLWRs is given for each DOE site evaluated in this NI PEIS in Table J–3. This distance and population would also bound shipments to and from Canada, if DOE should consider the use of a CANDU reactor in the future. Alternatives 3 and 4 include irradiation at a hypothetical facility located on an unspecified DOE site. For shipments originating at or destined for the unspecified reactor or accelerator site, a distance that bounds the furthest major DOE site is used.

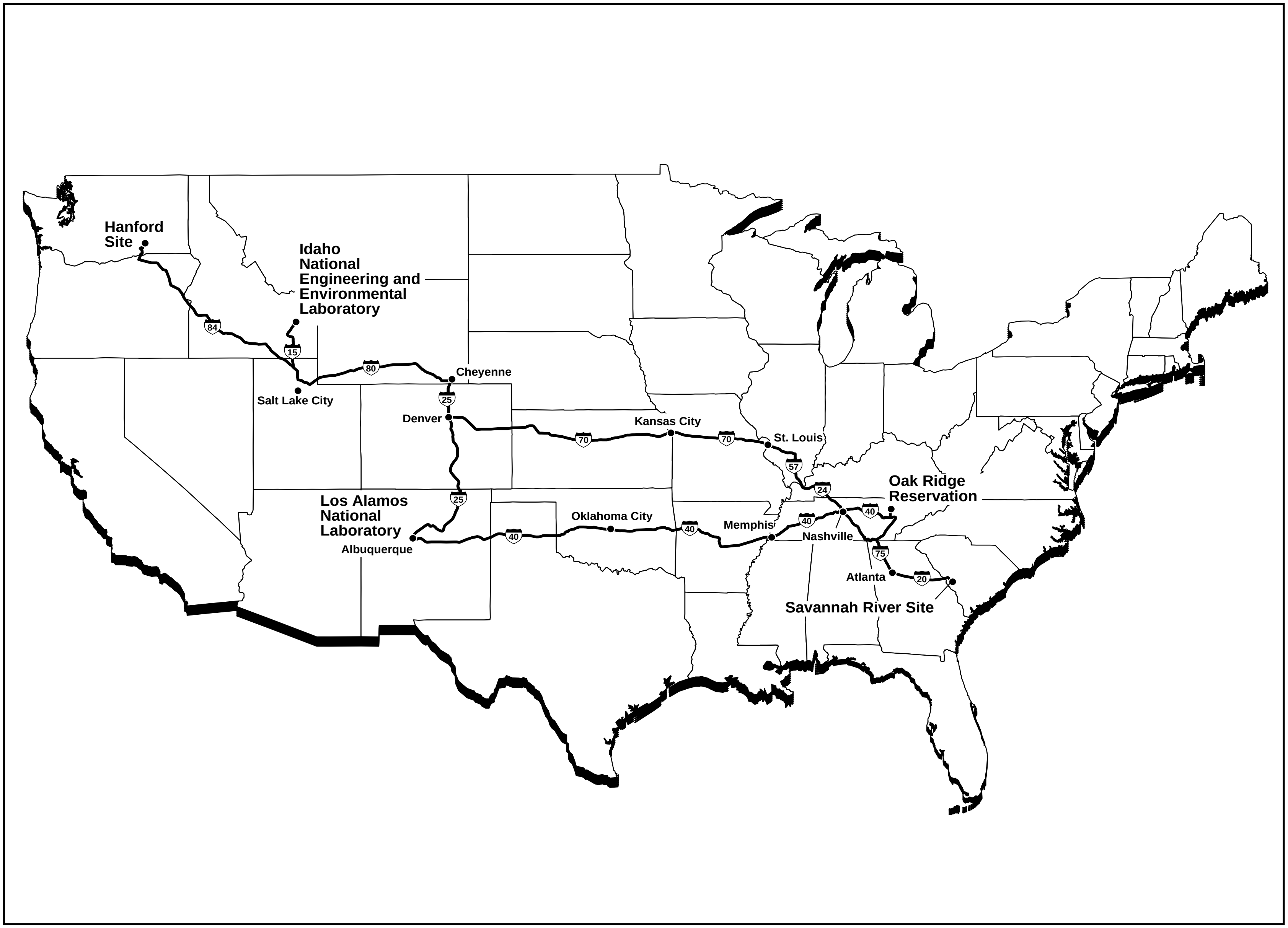


Figure J–9 Representative Overland Truck Routes

Table J–4 Potential Shipping Routes Evaluated for This NI PEIS

From	To	Distance (km)	Percentages in Zones			Population Density in Zone (1/km)			Number of Affected Persons
			Rural	Suburban	Urban	Rural	Suburban	Urban	
SRS	ORR (REDC)	604	60.8	36.0	3.2	18	334	2,195	194,424
SRS	INEEL (FDPF)	3,729	82.8	15.4	1.8	7	352	2,178	593,236
SRS	Hanford (FMEF)	4,429	84.3	14.0	1.6	7	359	2,169	642,594
ORR (REDC or HFIR)	INEEL (ATR or FDPF)	3,320	86.7	11.9	1.4	6	344	2,188	409,700
ORR (HFIR)	Hanford (FMEF)	4,020	87.7	11.0	1.3	6	355	2,175	466,713
INEEL (FDPF)	INEEL (ATR)	5	100	0.0	0.0	1	0	0	8
INEEL (ATR)	Hanford (FMEF)	1,007	92.0	7.4	0.5	6	384	1,984	70,108
ORR (REDC)	CLWR[a]	4,000	84.0	15.0	1.0	6	719	3,861	969,600
INEEL (FDPF)	CLWR[a]	4,700	84.0	15.0	1.0	6	719	3,861	1,139,280
Hanford (FMEF)	CLWR[a]	5,400	84.0	15.0	1.0	6	719	3,861	1,308,960
ORR (REDC)	Generic accelerator or reactor site[b]	4,000	84.0	15.0	1.0	6	719	3,861	969,600
INEEL (FDPF)	Generic accelerator or reactor site[b]	4,000	84.0	15.0	1.0	6	719	3,861	969,600
Hanford (FMEF)	Generic accelerator or reactor site[b]	4,500	84.0	15.0	1.0	6	719	3,861	1,090,800
Fuel fabricator	Generic reactor site	4,000	84.0	15.0	1.0	6	719	3,861	
ORR (REDC)	LANL	2,383	85.6	12.5	1.9	8	340	2,171	346,554
INEEL (FDPF)	LANL	1,846	89.2	9.4	1.4	4	383	2,093	204,112
Hanford (FMEF)	LANL	2,546	90.2	8.7	1.2	4	396	2,085	258,327
ORNL	Hanford 300 Area	3,834[c]	88.2	10.7	1.1	6	342	2,088	401,048
Hanford RPL	FFTF	14	71.4	28.6		2	89		614
Hanford RPL	Pasco Airport	32	68.8	28.1	1.0	6	342	2,088	6,218
Boston Airport	Dupont-Merck	35	14.3	51.4	34.3	15	479	2,564	61,336
Chicago Airport	Amersham Mediphysics	32	21.9	25.0	53.1	8	670	2,829	85,580
St. Louis Airport	Mallinckrodt	13	7.7	46.2	46.2	2	778	2,611	32,574
Hanford RPL	Hanford 200-East Area	35	97.2	2.9		2	90		276
Hanford RPL	Hanford 200-West Area	43	90.7	9.3		2	90		724
Charleston Naval Weapons Station	FFTF	4,677	84.8	13.8	1.3	7.2	342	2,157	609,025
ORR (Y–12)	B&W Lynchburg	550	66.5	32.6	0.9	19.5	283	2,029	108,804
B&W Lynchburg	FFTF	4,516	86.1	12.6	1.3	7.4	354	2,182	573,596
Generic fuel fabricator	Hypothetical site	4,500	84.0	15.0	1.0	6.0	719	3,861	1,090,800

a. CLWR site is assumed to be the furthest operating pressurized water reactor from the processing facility.
b. Bounding distance for a new reactor or accelerator constructed on an existing DOE site.
c. Using routes other than those designated for a vehicle carrying a Highway Route Controlled Quantity of a hazardous material; used by a vehicle carrying unirradiated medical isotope targets. All other routes selected are for Highway Route Controlled Quantities (49 CFR Part 397, Subpart D).

Note: 1 kilometer = 0.62 mile; 1 square kilometer = 0.39 square mile.

Key: km, kilometer; mi, mile.

J.5.5 External Dose Rates

In absence of analytical information, all shipments of neptunium-237, irradiated targets and plutonium-238 are conservatively assumed to be at the regulatory limit of 10 millirems per hour at a distance of 2 meters (6.6 feet) from the outer surface of the vehicle. The unirradiated targets, shipped in the same shielded cask as the irradiated targets, are assumed to be at one-tenth the regulatory limit. Other dose rates are estimated from cask contents.

J.5.6 Health Risk Conversion Factors

The health risk conversion factors used to estimate expected latent cancer fatalities were 0.0005 and 0.0004 fatal cancer cases per person-rem for members of the public and workers, respectively (ICRP 1991).

J.5.7 Accident Frequencies

For the calculation of accident risks, vehicle accident and fatality rates are taken from data provided in ANL-ESD/TM-150 (Saricks and Tompkins 1999). Accident rates are generically defined as the number of accident involvements (or fatalities) in a given year per unit of travel in that same year. Therefore, the rate is a fractional value, with accident-involvement count as the numerator of the fraction and vehicular activity (total travel distance in truck-kilometers) as its denominator. Accident rates are generally determined for a multiyear period. For assessment purposes, the total number of expected accidents or fatalities is calculated by multiplying the total shipment distance for a specific case by the appropriate accident or fatality rate.

For truck transportation, the rates presented are specifically for heavy combination trucks involved in interstate commerce (Saricks and Tompkins 1999). Heavy combination trucks are rigs composed of a separable tractor unit containing the engine and one to three freight trailers connected to each other. Heavy combination trucks are typically used for radioactive waste shipments. The truck accident rates are computed for each state based on statistics compiled by the Federal Highway Administration, Office of Motor Carriers from 1994 to 1996. A fatality caused by an accident is the death of a member of the public who is killed instantly or dies within 30 days due to the injuries sustained in the accident.

The HIGHWAY code classifies highways as rural, suburban or urban, and provides the distance and population information for use in RADTRAN. These codes require accident frequency data calculated for rural, urban and suburban zones. An older report, TM-68 (Saricks and Kvitek 1994), reports accident rates for Federally Aided Interstates in urban and rural areas, and a composite accident rate for all Federally Aided Interstates. TM-150 does not provide data that can be directly used to estimate frequencies for rural, urban and suburban zones. The ratio's of accident frequencies for the zones was calculated from TM-68 data, and used with the newer TM-150 data to establish up-to-date accident frequency estimates. Since the distance traveled on non-interstate highways was very small compared to the distance traveled on interstates, and the accident rates are similar, interstate accident rates were used for all roads. TM-68 and TM-150 information is used for both the accident rate estimate for the radiological risk, and the fatal accident rate estimate for the nonradiological risk.

For SST transportation, the rates presented are specifically adjusted for the experience of the DOE Transportation Safeguards Division. Between fiscal year 1984 and fiscal year 1998, the Transportation Safeguards Division reports 0.058 accident per million kilometers (0.096 accident per million miles). Using influence factors from SAND93-0111 (Phillips, Clauss, and Blower 1994), accident frequencies for rural, urban, and suburban driving can be estimated.

J.5.8 Container Accident Response Characteristics and Release Fractions

NUREG-0170 (NRC 1977) was used to estimate the conditional probabilities and release fractions associated with the neptunium-237, plutonium-238, and highly enriched uranium shipments. The Modal Study, an initiative taken by NRC (Fischer et al. 1987) to refine more precisely the analysis presented in NUREG-0170 (NRC 1977) for spent nuclear fuel shipping casks, was used to estimate the conditional probabilities and release fractions for target and nuclear fuel shipments. The release fractions used for the analysis of medical and industrial isotopes are based on the severity of the accident, the shipping container, and the material being shipped (Lavender and Nielsen 1997).

Whereas the NUREG-0170 analysis was primarily performed using best engineering judgments and presumptions concerning cask response, the Modal Study relies on sophisticated structural and thermal engineering analysis and a probabilistic assessment of the conditions that could be experienced in severe transportation accidents. The Modal Study results are based on representative spent nuclear fuel casks that were assumed to have been designed, manufactured, operated, and maintained in accordance with national codes and standards. Design parameters of the representative casks were chosen to meet the minimum test criteria specified in 10 CFR Part 71. The study is believed to provide realistic, yet conservative, results for radiological releases under transport accident conditions.

In both NUREG-0170 and the Modal Study, potential accident damage to a cask is categorized according to the magnitude of the mechanical forces (impact) and thermal forces (fire) to which a cask may be subjected during an accident. Because all accidents can be described in these terms, severity is independent of the specific accident sequence. In other words, any sequence of events that results in an accident in which a cask is subjected to forces within a certain range of values, it is assigned to the accident severity region associated with that range. The accident severity scheme is designed to take into account all potential foreseeable transportation accidents, including accidents with low probability but high consequences and those with high probability but low consequences.

As discussed above, the accident consequence assessment only considers the potential impacts from the most severe transportation accidents. In terms of risk, the severity of an accident must be viewed in terms of potential radiological consequences, which are directly proportional to the fraction of the radioactive material within a cask that is released to the environment during the accident. Although regions span the entire range of mechanical and thermal accident loads, they are grouped into accident categories that can be characterized by a single set of release fractions and are, therefore, considered together in the accident consequence assessment. The accident category severity fraction is the sum of all conditional probabilities in that accident category. NUREG-0170 (NRC 1977) provides eight accident severity categories for the neptunium-237 and plutonium-238. The Modal Study (Fischer et al. 1987) provides six accident severity categories for the targets.

J.5.9 Nonradiological Risk (Vehicle-Related)

Vehicle-related health risks resulting from incident-free transport may be associated with the generation of air pollutants by transport vehicles during shipment and are independent of the radioactive nature of the shipment. The health end-point assessed under incident-free transport conditions is the excess latent mortality due to inhalation of vehicle exhaust emissions. Risk factors for pollutant inhalation in terms of latent mortality have been generated (Neuhauser and Kanipe 2000). These risks are 1×10^{-7} mortality per kilometer (1.6×10^{-7} per mile) of truck travel in urban areas. The risk factors are based on regression analyses of the effects of sulfur dioxide and particulate releases from diesel exhaust on mortality rates. Excess latent mortalities are assumed to be equivalent to latent cancer fatalities. Vehicle-related risks from incident-free transportation are calculated for each case by multiplying the total distance traveled in urban areas by the appropriate risk factor. Similar data are not available for rural and suburban areas.

Risks are summed over the entire route and over all shipments for each case. This method has been used in several EISs to calculate risks from incident-free transport. Lack of information for rural and suburban areas is an apparent data gap, although the risk factor would be much lower than for urban areas because of lower total emissions from all sources and lower population densities in rural and suburban areas.

J.5.10 Intrasite Shipment

If HFIR is selected to irradiate and REDC to process the targets, targets would be transported the short distance between REDC and HFIR in a cask that was formerly certified to Type B standards. Since the move is only about 90 meters (100 yards) on closed roads, and entirely on ORR, DOE procedures and NRC regulations do not require the use of a certified Type B cask. No incident-free risk analysis is necessary, because the public would receive no measurable exposure. Similar procedures and equipment would be used at INEEL for transfers between FDPF and ATR. Worker dose would be included in the handling analysis. No accident analysis is necessary because potential accidents during transportation are bounded in frequency and consequence by handling accidents. Once the cask is closed for the low speed transportation to the nearby building, the likelihood of any foreseeable accident that could expose the cask to conditions severe enough to fail the cask are very small.

At Hanford, the distances between facilities is somewhat larger and the roads could remain open for traffic. Therefore, DOE plans to use certified packaging. Risk analysis for unirradiated and irradiated plutonium-238, and medical and industrial isotope targets have been included. The facility locations for the new reactor and accelerator have not been established, so the risk analysis used is the same parameters as for Hanford.

J.6 Risk Analysis Results

J.6.1 Transportation Risk Analysis

Per-shipment risk factors have been calculated for the collective populations of exposed persons and for the crew for all anticipated routes and shipment configurations. The radiological doses are presented in doses per shipment for each unique route, material, and container combination. The radiological dose per shipment factors for incident-free transportation are presented in **Table J–5**. The per-shipment doses from medical and industrial isotopes come from HNF-1844 (Lavender and Nielsen 1997). The impacts from importing plutonium-238 were scaled from DOE/EA-0841 (DOE 1993) as described in Section 4.2.1.1. Doses are calculated for the crew, off-link public (i.e., people living along the route), on-link public (i.e., pedestrians and drivers along the route), and public at rest and fueling stops (i.e., stopped cars, buses and trucks, workers, and other bystanders).

The radiological dose risk factors for transportation accidents are also presented in Table J–5. The accident risk factors are called "dose risk" because the values incorporate the spectrum of accident severity probabilities and associated consequences. Commercial vehicles have higher nonradiological and radiological accident risks because of the lower accident frequency calculated for SST/SGTs. The SST/SGTs have lower public risk estimates because they only stop in secure locations. The commercial vehicles have lower emission risk estimates because the SST/SGTs travel with escort vehicles. Crew risks are about the same.

The nonradiological risks of transporting each of the hazardous materials on the various routes are given in **Table J–6**. The risks are calculated by multiplying the previously given per-shipment factors by the number of shipments over the 35-year duration of the program. The risk estimates include the highest conceivable impacts of shipping. The total exhaust emission risks are higher if SST/SGTs are used because of the additional emission of escort vehicles. The accident risk of escort vehicles was considered in the analysis of traffic accident risk.

Table J–7 shows the risks of transportation for each alternative. The risks are calculated by multiplying the previously given per-shipment factors by the number of shipments over the duration of the program, and for the radiological doses, by the health risk conversion factors. The risks are summed for all material transported under each alternative. The risks shown in Table J–7 conservatively assume that the neptunium-237, mixed oxide fuel, highly enriched uranium fuel, and plutonium-238 would be shipped in an SST/SGT and that all other intersite transportation would be done in commercial vehicles. Use of SST/SGTs for other shipments would lower the radiological risk estimates. They include the risk from overland, sea and air transportation to the vessel crews and the public.

The accident consequence assessment is intended to provide an estimate of the maximum potential impacts posed by the most severe hypothetical transportation accidents involving a shipment of materials covered by this NI PEIS. As a practical matter, the maximum foreseeable transportation accident is defined as an accident with a frequency greater than 1×10^{-7} per year (once in 10 million years). The previously described risk assessment (RADTRAN analysis) takes into account the risk of accidents not considered in the consequence assessment. The risk of accidents with frequencies lower than 1×10^{-7} per year is included in the risk estimates shown in Table J–7.

Table J–5 Radiological Dose for Incident-Free Transportation and Accident Dose-Risk Factors

				Incident-Free Dose (person-rem)					
					Public				Accident Dose-Risk[a] (person-rem)
From	To	Material	Vehicle	Crew	Off-link	On-link	Stops	Total	
SRS	ORR	Neptunium-237	SST/SGT	0.0049	0.0087	0.0024	0.028	0.061	8.3×10^{-7}
			Truck	0.0049	0.0087	0.0024	0.10	0.14	4.0×10^{-6}
SRS	INEEL		SST/SGT	0.031	0.025	0.13	0.17	0.33	2.6×10^{-6}
			Truck	0.031	0.025	0.13	0.64	0.79	0.000012
SRS	Hanford		SST/SGT	0.036	0.027	0.15	0.21	0.38	2.9×10^{-6}
			Truck	0.036	0.027	0.15	0.76	0.94	0.00014
ORR	INEEL	Unirradiated neptunium-237 targets	SST/SGT	0.0021	0.0015	0.0097	0.013	0.025	7.5×10^{-10}
			Truck	0.0021	0.0015	0.0098	0.049	0.061	3.6×10^{-9}
ORR	Hanford		SST/SGT	0.0025	0.0017	0.012	0.016	0.030	8.1×10^{-10}
			Truck	0.0025	0.0017	0.012	0.060	0.073	4.1×10^{-9}
ORR	CLWR		SST/SGT	0.0025	0.0043	0.012	0.016	0.032	1.8×10^{-9}
			Truck	0.0025	0.0043	0.012	0.060	0.076	8.8×10^{-9}
INEEL	CLWR		SST/SGT	0.0030	0.0050	0.014	0.019	0.038	2.1×10^{-9}
			Truck	0.0030	0.0050	0.014	0.070	0.089	1.0×10^{-8}
Hanford	INEEL		SST/SGT	0.00064	0.00033	0.0028	0.004	0.007	1.3×10^{-10}
			Truck	0.00064	0.00033	0.0028	0.015	0.018	6.4×10^{-10}
Hanford	CLWR		SST/SGT	0.0034	0.0058	0.016	0.022	0.044	2.4×10^{-9}
			Truck	0.0034	0.0058	0.016	0.080	0.10	1.2×10^{-8}
ORR	Reactor		SST/SGT	0.0026	0.0043	0.012	0.016	0.032	1.8×10^{-9}
			Truck	0.0026	0.0043	0.012	0.060	0.076	8.8×10^{-9}
INEEL	Reactor		SST/SGT	0.0026	0.0043	0.012	0.016	0.032	1.8×10^{-9}
			Truck	0.0026	0.0043	0.012	0.060	0.076	8.8×10^{-9}
Hanford	Reactor		SST/SGT	0.0028	0.0048	0.013	0.018	0.036	2.0×10^{-9}
			Truck	0.0028	0.0048	0.013	0.067	0.085	9.9×10^{-9}

Table J–5 Radiological Dose for Incident-Free Transportation and Accident Dose-Risk Factors (Continued)

From	To	Material	Vehicle	Incident-Free Dose (person-rem)					Accident Dose-Risk[a] (person-rem)
					Public				
				Crew	Off-link	On-link	Stops	Total	
ORR	Accelerator	Unirradiated neptunium-237 targets	Truck	0.0026	0.0043	0.012	0.060	0.076	1.1×10^{-6}
INEEL	Accelerator		Truck	0.0026	0.0043	0.012	0.060	0.076	1.1×10^{-6}
Hanford	Accelerator		Truck	0.0043	0.0056	0.015	0.077	0.098	1.3×10^{-6}
CLWR	ORR	Irradiated neptunium-237 targets	Truck	0.041	0.049	0.14	0.68	0.87	4.3×10^{-8}
CLWR	INEEL		Truck	0.048	0.058	0.16	0.80	1.02	5.1×10^{-8}
INEEL	Hanford		Truck	0.010	0.0037	0.032	0.17	0.21	3.1×10^{-9}
CLWR	Hanford		Truck	0.055	0.066	0.18	0.02	0.27	5.9×10^{-8}
Accelerator or reactor	Hanford		Truck	0.046	0.055	0.15	0.77	0.98	1.6×10^{-7}
Accelerator or reactor	ORR		Truck	0.041	0.049	0.14	0.68	0.87	1.4×10^{-7}
Accelerator or reactor	INEEL		Truck	0.041	0.049	0.14	0.68	0.87	1.4×10^{-7}
Accelerator	ORR		Truck	0.038	0.049	0.14	0.68	0.87	7.2×10^{-4}
Accelerator	INEEL		Truck	0.038	0.049	0.14	0.68	0.87	7.2×10^{-4}
			Truck	0.043	0.056	0.15	0.77	0.98	8.1×10^{-4}
ORR	LANL	Plutonium-238	SST/SGT	0.020	0.00090	0.0055	0.0024	0.0088	0.0025
			Truck	0.020	0.00090	0.0055	0.0094	0.016	0.0012
INEEL	LANL		SST/SGT	0.015	0.00056	0.0042	0.0020	0.0067	0.0012
			Truck	0.015	0.00056	0.0042	0.0073	0.012	0.0058
Hanford	LANL		SST/SGT	0.021	0.00074	0.0057	0.0027	0.0092	0.0017
			Truck	0.021	0.00074	0.0057	0.010	0.017	0.0080
Europe	CNWS	SNR–300	Ship	0.0027					1.3×10^{-10}
CNWS	Hanford	Mixed oxide fuel C1	SST/SGT	0.012	0.0012	0.0080	0.0030	0.012	2.5×10^{-8}
Europe	CNWS	SNR–300	Ship	0.0027					1.8×10^{-10}
CNWS	Hanford	Mixed oxide fuel C2	SST/SGT	0.012	0.0012	0.0080	0.0030	0.012	3.4×10^{-8}

Table J–5 Radiological Dose for Incident-Free Transportation and Accident Dose-Risk Factors (Continued)

From	To	Material	Vehicle	Incident-Free Dose (person-rem)					Accident Dose-Risk[a] (person-rem)
					Public				
				Crew	Off-link	On-link	Stops	Total	
ORR	Fuel fabricator	Highly enriched uranium fuel	SST/SGT	0.00095	0.000035	0.00026	0.000039	0.00033	3.3×10^{-10}
Fuel fabricator	Hanford	Highly enriched uranium fuel	SST/SGT	0.012	0.0011	0.0077	0.0030	0.012	1.6×10^{-13}
Fuel fabricator	Reactor site	Low-enriched uranium fuel	Truck	0.0029	0.0049	0.00039	0.067	0.072	4.5×10^{-10}

a. Dose-risk factor = dose (due to accidents) + accident frequencies.

Key: SST/SGT, safe, secure trailer/SafeGuards Transport.

Table J–6 Nonradiological Risk Factors per Shipment

Routes		Exhaust Emissions (latent cancer fatalities)		Accidents (fatalities)	
From	To	Truck	SST/SGT	Truck	SST/SGT
SRS	ORR (REDC)	3.9×10^{-6}	5.0×10^{-6}	0.00023	3.6×10^{-6}
SRS	INEEL (FDPF)	0.000013	0.000017	0.00011	0.000015
SRS	Hanford (FMEF)	0.000014	0.000018	0.00013	0.000018
ORR (REDC or HFIR)	INEEL (ATR)	9.3×10^{-6}	0.000012	0.000094	0.000013
ORR (HFIR)	Hanford (FMEF)	0.00001	0.000014	0.00011	0.000015
INEEL (FDPF)	INEEL (ATR)	0	0	1.1×10^{-7}	1.3×10^{-8}
INEEL (ATR)	Hanford (FMEF)	1.0×10^{-6}	1.3×10^{-6}	0.000026	3.5×10^{-6}
ORR (REDC)	CLWR	8.0×10^{-6}	0.00001	0.00012	0.000016
INEEL (FDPF)	CLWR	9.4×10^{-6}	0.000012	0.00014	0.000019
Hanford (FMEF)	CLWR	0.000011	0.000014	0.00016	0.000022
ORR (REDC)	Generic accelerator or reactor site[a]	8.0×10^{-6}	1.0×10^{-5}	1.2×10^{-4}	1.6×10^{-5}
INEEL (FDPF)	Generic accelerator or reactor site[a]	8.0×10^{-6}	1.0×10^{-5}	1.2×10^{-4}	1.6×10^{-5}
Hanford (FMEF)	Generic accelerator or reactor site[a]	9.0×10^{-6}	1.2×10^{-5}	1.3×10^{-4}	1.8×10^{-5}
Fuel fabricator	Generic reactor site	9.0×10^{-6}	1.2×10^{-5}	1.3×10^{-4}	1.8×10^{-5}
ORR REDC	LANL	9.1×10^{-6}	0.000012	0.000068	9.3×10^{-6}
INEEL FDPF	LANL	5.2×10^{-6}	6.7×10^{-6}	5.0×10^{-6}	6.7×10^{-6}
Hanford FMEF	LANL	6.1×10^{-6}	7.9×10^{-6}	6.8×10^{-6}	9.1×10^{-6}
ORNL	Hanford 300 Area	8.5×10^{-6}	1.1×10^{-5}	1.06×10^{-4}	1.4×10^{-5}
Hanford RPL	FFTF			4.9×10^{-7}	7.4×10^{-8}
Hanford RPL	Pasco Airport	6.4×10^{-8}	NA	1.1×10^{-6}	NA
Boston Airport	Dupont-Merck	2.3×10^{-6}	NA	1.6×10^{-6}	NA
Chicago Airport	Amersham Mediphysics	3.4×10^{-6}	NA	1.2×10^{-6}	NA
St. Louis Airport	Mallinckrodt	1.2×10^{-6}	NA	6.0×10^{-7}	NA
Charleston Naval Weapons Station	FFTF	1.2×10^{-5}	1.6×10^{-5}	1.4×10^{-4}	1.9×10^{-5}
Y–12	B&W fuel	9.9×10^{-7}	1.3×10^{-6}	2.0×10^{-5}	3.1×10^{-6}
B&W fuel	FFTF	1.2×10^{-5}	1.5×10^{-5}	1.3×10^{-4}	1.8×10^{-5}
Fuel fabrication	Site	9.0×10^{-6}	1.2×10^{-5}	1.3×10^{-4}	1.8×10^{-5}

a. Bounding distance for a new accelerator or reactor constructed on an existing DOE site.

Key: ATR, Advanced Test Reactor; CLWR, commercial light water reactor; FDPF, Fluorinel Dissolution Process Facility; FMEF, Fuels and Materials Examination Facility; HFIR, High Flux Isotope Reactor; REDC, Radiochemical Engineering Development Center; RPL, Radiochemical Processing Laboratory; SST/SGT, safe, secure trailer/SafeGuards Transport.

Table J–7 Risks of Transporting the Hazardous Materials

#	Alternative	Combinations (Target Fabrication and Processing/Reactors)	Shipments[a]	Distance Traveled[b] (km)	Incident-Free Risk[c]				Accident Risk[c]
					Radiological		Nonradiological		
					Crew	Public	Emission	Traffic	Radiological
	No Action Option 1	—	35	113,750	0.0046	0.0099	0.00047	0.014	4.4×10^{-4}
	No Action Option 2	Storage of neptunium at ORR	133	172,893	0.0048	0.013	0.00097	0.014	4.4×10^{-4}
	No Action Option 3	Storage of neptunium at INEEL	133	479,163	0.0058	0.026	0.0022	0.016	4.4×10^{-4}
	No Action Option 4	Storage of neptunium at Hanford	133	547,772	0.0060	0.029	0.0023	0.016	4.4×10^{-4}
1	Restart FFTF Option 1	Production[d] at ORR and irradiation at FFTF with MOX and HEU	903	3,300,245	0.0066	0.15	0.010	0.073	4.4×10^{-5}
1	Restart FFTF Option 2	Production at INEEL and irradiation at FFTF with MOX and HEU	903	1,689,764	0.0034	0.053	0.005	0.021	2.1×10^{-5}
1	Restart FFTF Option 3	Production at Hanford and irradiation at FFTF with MOX and HEU	903	1,157,032	0.0024	0.020	0.004	0.0045	3.0×10^{-5}
1	Restart FFTF Option 4	Production at ORR and irradiation at FFTF with HEU	888	3,203,937	0.0064	0.15	0.009	0.073	4.4×10^{-5}
1	Restart FFTF Option 5	Production at INEEL and irradiation at FFTF with HEU	888	1,593,456	0.0033	0.05	0.0044	0.020	2.1×10^{-5}
1	Restart FFTF Option 6	Production at Hanford and irradiation at FFTF with HEU	888	1,060,724	0.0023	0.020	0.0039	0.0041	3.0×10^{-5}
2	Existing Facility Option 1	Production at ORR and irradiation at INEEL	763	2,234,162	0.0050	0.12	0.0068	0.060	4.4×10^{-5}
2	Existing Facility Option 2	Production and irradiation at INEEL	133	430,019	0.0014	0.016	0.0019	0.0017	2.1×10^{-5}
2	Existing Facility Option 3	Production at Hanford and irradiation at INEEL	763	1,157,791	0.0031	0.055	0.0027	0.019	3.0×10^{-5}
2	Existing Facility Option 4	Production at ORR and irradiation at a CLWR	763	2,662,562	0.0059	0.15	0.0059	0.075	4.4×10^{-5}
2	Existing Facility Option 5	Production at INEEL and irradiation at a CLWR	763	3,391,019	0.0078	0.19	0.0079	0.089	2.1×10^{-5}
2	Existing Facility Option 6	Production at Hanford and irradiation at a CLWR	763	3,925,129	0.0090	0.22	0.0089	0.102	3.0×10^{-5}

Table J–7 Risks of Transporting the Hazardous Materials (Continued)

#	Alternative	Combinations (Target Fabrication and Processing/Reactors)	Shipments[a]	Distance Traveled[b] (km)	Incident-Free Risk[c]			Accident Risk[c]	
					Radiological		Nonradiological		
					Crew	Public	Emission	Traffic	Radiological
	Existing Facility Option 7	Production at ORR and irradiation at ORR and INEEL	637	1,815,842	0.0041	0.098	0.0056	0.048	4.4×10^{-5}
	Existing Facility Option 8	Production at INEEL and irradiation at ORR and INEEL	385	1,266,659	0.0033	0.064	0.0043	0.025	4.4×10^{-5}
	Existing Facility Option 9	Production at Hanford and irradiation at ORR and INEEL	763	1,916,966	0.0047	0.098	0.0051	0.040	3.0×10^{-5}
3	New Accelerator Option 1	Production at ORR and irradiation in accelerator[e]	343	982,562	0.0022	0.053	0.0026	0.025	8.1×10^{-5}
	New Accelerator Option 2	Production at INEEL and irradiation in accelerator[e]	343	1,270,019	0.0032	0.066	0.0036	0.026	8.2×10^{-5}
	New Accelerator Option 3	Production at Hanford and irradiation in accelerator[e]	343	1,468,129	0.0037	0.076	0.0040	0.030	7.2×10^{-5}
4	New Reactor Option 1	Production at ORR and irradiation in a new research reactor	783	2,752,562	0.0056	0.15	0.0061	0.077	4.8×10^{-5}
	New Reactor Option 2	Production at INEEL and irradiation in a new research reactor	783	3,040,019	0.0066	0.17	0.0072	0.078	4.8×10^{-5}
	New Reactor Option 3	Production at Hanford and irradiation in a new research reactor	783	3,448,129	0.0075	0.19	0.0079	0.083	3.5×10^{-5}
5	Deactivate FFTF	—	—	~0	~0	~0	~0	~0	~0
Alternatives 1, 3, and 4		Maximum transportation impacts of producing and distributing isotopes[f]	36,750	4,765,110	0.0059	0.0037	0.020	0.112	0.531

a. "Shipments" means the number of transportation legs. For example, a package that is loaded onto a truck, driven to an airport, flown to another airport, loaded onto a truck and shipped to a final destination would count as three shipments (two by truck, one by air).
b. Distance traveled by trucks carrying radiological materials. Nonradiological impacts used two-way transportation.
c. All risks are expressed as number of latent cancer fatalities, except for the Accident-Traffic column, which lists number of accident fatalities.
d. Production means storage, target fabrication, and processing.
e. These are the transportation impacts for the high-energy accelerator.
f. These are the transportation impacts for the low-energy accelerator.

Key: CLWR, commercial light water reactor; HEU, highly enriched uranium fuel; km, kilometers; MOX, mixed oxide fuel.

Source: Calculated results.

Accidents involving neptunium-237, mixed oxide fuel, irradiated targets, and plutonium-238 were evaluated in the consequence assessment. Accidents involving unirradiated targets were not evaluated because they occur at the same frequency, but clearly have lower consequences than accidents involving irradiated targets. SST/SGT accidents with higher frequencies than 1×10^{-7} per year did not release any neptunium-237 or plutonium-238 to the environment because the temperature and mechanical stresses predicted for accidents in this frequency range are within the design basis of the packages. The maximum foreseeable offsite transportation accident involves a shipment of irradiated plutonium-238 targets under neutral (average) weather conditions. The accident has a probability of occurring about once every 10 million years for the alternatives that involve shipping radioactive targets from one DOE facility to another. The accident could result in a dose of 0.61 person-rem to the public with an associated 3.1×10^{-4} latent cancer fatalities and 2.6 millirem to a hypothetical maximally exposed individual 30 meters (about 100 feet) from the vehicle. This results in a latent fatal cancer risk of 1.3×10^{-6}. No immediate fatalities from radiation would be expected. This accident would fall into Severity Category V (Fischer et al. 1987). In this hypothetical accident, the impact would cause the cask to fail, and the deformation of the cask would be assumed to fail a portion of the target material. In the event of a fire, it would not be hot enough or would not last long enough to damage the targets. To incur this level of damage, the cask would have to collide with an immovable object at a speed of greater than 88.5 kilometers (55 miles) per hour. The probability of an accident with a more energetic collision or fire and higher consequences is lower.

For alternatives and options in which irradiated targets are not shipped offsite, but mixed fuel is received at an east coast port, the maximum forseeable offsite transportation accident is a shipment of mixed oxide fuel. This Category V accident in a suburban population zone could result in a dose of 0.40 person-rem to the public with an associated 2.0×10^{-4} latent cancer fatality, and 3.3 millirem to the hypothetical maximally exposed individual. No fatalities would be expected as a result of the radiation exposure.

The risks to various exposed individuals under incident-free transportation conditions have been estimated for hypothetical exposure scenarios. The estimated doses to inspectors and the public are presented in **Table J–8** on a per-event basis (person-rem per event). Note that the potential exists for larger individual exposures if multiple exposure events occur. For example, the dose to a person stuck in traffic next to a shipment for 30 minutes is calculated to be 11 millirem. If the exposure duration were longer, the dose would rise proportionally. In addition, a person working at a truck service station could receive a dose if trucks were to use the same stops repeatedly. The dose to a person fueling a truck could be as much as 1 millirem. Administrative controls could be instituted to control the location and duration of truck stops if multiple exposures were to happen routinely.

Table J–8 Estimated Dose to Exposed Individuals During Incident-Free Transportation Conditions

Receptor		Dose to Maximally Exposed Individual[a]
Workers	Crew member (truck driver)	0.1 rem per year[b]
	Inspector	0.0029 rem per event
Public	Resident	4.0×10^{-7} rem per event
	Person in traffic congestion	0.011 rem per event
	Person at service station	0.001 rem per event

a. Doses are calculated assuming that the shipment external dose rate is equal to the maximum expected dose of 10 millirem per hour at 2 meters (6.6 feet) from the package.
b. This is a dose limit for a nonradiation worker (10 CFR Part 20). The dose to the truck driver could exceed this limit in the absence of administrative controls.

The cumulative dose to a resident was calculated assuming all shipments passed the resident's home. The cumulative doses assume that the resident is present for every shipment and there is no shielding between the package and the receptor at a distance of 30 meters (about 100 feet) from the route. If all the material were to be shipped via this route, the maximum dose to this resident would be less than 0.1 millirem.

The estimated dose to transportation crew members is presented for a commercial crew who would be limited to 0.1 rem per year by 10 CFR Part 20. Drivers of SST/SGTs and some commercial trucks are trained as radiological workers. Allowed exposure limits vary. The exposure is limited to 2 millirem per hour in a "normally occupied space," in accordance with 10 CFR Section 71.47.

J.6.2 Marine Transport Risk Analysis for Mixed Oxide Fuel

The potential impacts of marine transport of mixed oxide fuel were considered in two ways, incident-free and accident impacts. Impact analysis includes the impacts on the global commons (i.e., portions of the ocean not within the territorial boundary of any nation) in accordance with Executive Order 12114 (44 FR 1957), the impacts approaching and docking at the port, and the impacts of unloading the mixed oxide package at the port.

The incident-free impacts would be those that occur simply due to the marine shipping of the mixed oxide fuel, assuming there are no accidents. The ships crew and dock crew would be affected in this case. The previously described RADTRAN 5 code was used to analyze the dose to the ships crew for transportation from Europe to the U.S. east coast. The accident impacts for the egress into the Charleston Naval Weapons Station were also modeled using the RADTRAN 5 code and are displayed in Table J–5.

The dose to the ships crew and the dockside personnel that would result from off loading the mixed oxide fuel packages was taken directly from the *Foreign Research Reactor Spent Nuclear Fuel EIS* (DOE 1996). The results are included in Table J–5 and are also in the by-alternative risk calculations shown in Table J–7. Exposure to handlers, inspectors, crane operators, and observers are included.

The *Foreign Research Reactor Spent Nuclear Fuel EIS* (DOE 1996) analyzed the shipment of spent nuclear fuel, and much of the analysis of shipping mixed oxide fuel can be taken from that document. The *Foreign Research Reactor Spent Nuclear Fuel EIS* is useful for both an absolute assessment of impacts and a relative assessment of impacts of using various ports. This NI PEIS analysis will show that the risk of shipping mixed oxide fuel is significantly less than the risk of shipping spent nuclear fuel by comparing the overland risk assessment of the two fuels. These risk assessments were both carried out using the same systematic approach to the analysis and using the RADTRAN series of codes.

Table J–9 shows the per-shipment risk estimates performed for a mixed oxide fuel shipment from Charleston Naval Weapons Station to Hanford and the comparable estimates for a shipment of spent nuclear fuel from Charleston Naval Weapons Station and 10 other ports to Hanford. The dock and channel accident risk is from Appendix D and Attachment 2 to the *Foreign Research Reactor Spent Nuclear Fuel EIS* (DOE 1996). It is based on direct shipment of BR–2 spent nuclear fuel to the ports and includes hypothetical accidents at a point in the channel near population centers and at the dock. For example, the channel accident for the Charleston, South Carolina, area was performed for an accident at commercial anchorage area D, which is near the city of Charleston. The remaining columns in Table J–9 are from RADTRAN analysis of overland transportation and is the same information provided in Table J–5.

Comparing the overland transportation risks of shipping mixed oxide fuel and spent nuclear fuel along the same route from Charleston, South Carolina, to Hanford indicates the relative risks of the two materials. The crew risk is about a factor of 20 higher for the spent nuclear fuel than for the mixed oxide fuel because the dose rate from the spent fuel package is estimated to be at least 20 times higher. Public risk is about 50 times higher because of this dose rate difference. Also, the mixed oxide fuel would be carried in SST/SGTs, which would

Table J–9 Per-Shipment Risk Estimates from Military Seaports to the Hanford Site

	Dock and Channel Accident Risk (LCF)	Incident-Free Risk				Accident Risk
		Radiological (Person - Rem)		Nonradiological (Fatalities)		Radiological (person-rem)
		Crew	Public	Emission	Traffic	
Eastern ports						
Charleston Naval Weapons Station, South Carolina (MOX)	Not analyzed	0.012	0.012	1.6×10^{-5}	1.9×10^{-5}	1.8×10^{-10}
Charleston Naval Weapons Station, South Carolina	1.3×10^{-9}	0.25	0.64	1.1×10^{-5}	0.00020	0.00015
Military Ocean Terminal Sunny Point, North Carolina	6.2×10^{-10}	0.25	0.64	1.2×10^{-5}	0.00018	0.00014
Mayport, Florida	1.5×10^{-9}	0.26	0.67	1.3×10^{-5}	0.00017	0.00017
Kings Bay, Georgia	1.2×10^{-9}	0.25	0.65	1.2×10^{-5}	0.00017	0.00015
Pensacola, Florida	1.2×10^{-9}	0.24	0.62	1.2×10^{-5}	0.00016	9.7×10^{-5}
Yorktown, Virginia	1.6×10^{-9}	0.25	0.65	1.2×10^{-5}	0.00016	0.00013
Hampton Roads, Virginia	2.1×10^{-9}	0.26	0.67	1.6×10^{-5}	0.00018	0.00014
Western ports						
Military Ocean Terminal Bay Area, California	7.1×10^{-9}	0.081	0.20	7.8×10^{-6}	4.8×10^{-5}	4.5×10^{-5}
Bremerton, Washington	3.1×10^{-9}	0.030	0.068	4.2×10^{-6}	1.1×10^{-5}	1.2×10^{-5}
Everett, Washington	3.4×10^{-9}	0.026	0.060	3.6×10^{-6}	1.0×10^{-5}	1.2×10^{-5}
Port Hueneme, California	6.0×10^{-9}	0.11	0.28	1.2×10^{-5}	0.00077	5.6×10^{-5}
Port Townsend, Washington	Not analyzed	0.035	0.080	3.3×10^{-5}	6.2×10^{-6}	1.4×10^{-5}

Note: All except the Charleston Naval Weapons Station, South Carolina (MOX) are for spent nuclear fuel shipments from DOE 1996. Charleston Naval Weapons Station, South Carolina (MOX) is for a shipment of mixed oxide fuel from the transportation analysis of this NI PEIS.
Key: LCF, latent cancer fatality, MOX, mixed oxide fuel.

not be expected to expose the public to as much radiation as commercial trucks. In the risk analysis, commercial trucks carrying spent nuclear fuel are assumed to stop for food, fuel, and rest in the same manner as typical long distance trucking practices. However, SST/SGTs have specific procedures to ensure fueling is performed in a safe and secure manner, and routine rest and inspection stops are done in secure areas. Truck emissions are estimated to be the same for SST/SGTs and commercial trucks, but the emission risk for the mixed oxide fuel is higher because the SST/SGTs travel with escorts. SST/SGT accident frequencies are about a factor of 20 lower than truck accident frequencies, but the risk estimate for nonradiological accidents is only a factor of 10 lower because of the increased accident risk associated with SST/SGT escort vehicles.

The overland transportation radiological risk is a factor of one million lower for mixed oxide fuel than for spent nuclear fuel. Part of this difference is because the accident frequency is about 20 times lower for SST/SGTs. The risk estimated in Table J–9 were calculated by multiplying frequencies time consequences. Since the risk is about one million times lower and the frequency is about 20 times lower, the consequences of the same spectrum of accidents for the mixed oxide fuel packages is 50,000 times lower than for spent nuclear fuel packages ($20\times50{,}000 = 1{,}000{,}000$). Based on the risk estimate of 1.3×10^{-9} latent cancer fatality per-shipment risk estimate for the foreign research reactor spent nuclear fuel package, the risk of shipping a mixed oxide fuel package into the port of Charleston Naval Weapons Station would be about 2.6×10^{-14} (1.3×10^{-9} divided by $50{,}000 = 2.6\times10^{-14}$).

Table J–9 shows the range of impacts calculated for the use of military ports for spent nuclear fuel, which can be used to estimate the range of impacts for mixed oxide fuel. Impacts of using the Charleston Naval Weapons

Station are representative (i.e., about the same) as for any of the east coast ports. Based on the estimate for the Charleston Naval Weapons Station, the dock and channel accident risk of bringing a mixed oxide fuel package into any of the east coast military ports listed in Table J–9 would be less than 10^{-13} latent cancer fatalities. The incident-free and accident risks would be about the same as Charleston Naval Weapons Station for any eastern port. The dock and channel accident risk for western ports would be higher than those for eastern ports because of the higher local populations, but all would be less than 10^{-12} latent cancer fatalities. The incident-free and accident risk for western ports ranges from about one-tenth to about one-half of those for eastern ports. The lower risk for western ports is caused by the reduced distance to Hanford.

The *Foreign Research Reactor Spent Nuclear Fuel EIS* (DOE 1996) evaluated the risks of damaged and undamaged casks sinking into coastal and deep ocean waters. The analysis included probabilities of recovery, and conservatively assumed failure of the cask in all accidents in greater than 200 meters of water depth. All program risks were less than 10^{-7} rem per year to the peak individual. Since mixed oxide fuel accident consequences are much lower and this NI PEIS is proposing fewer shipments than the *Foreign Research Reactor Spent Nuclear Fuel EIS*, all risks would be less than 10^{-10} rem per year for mixed oxide fuel alternatives to the maximally exposed individual. The *Foreign Research Reactor Spent Nuclear Fuel EIS* concluded that following a hypothetical severe accident, radioactive particles dispersed over the ocean would not be in large enough amounts to have a measurable impact on the environment. The same conclusion would be appropriate for this NI PEIS since the casks would contain considerably fewer curies of radioactive material.

J.7 CONCLUSIONS

The transportation requirements for the alternatives of the NI PEIS have been analyzed, and the following conclusions have been reached:

- It is unlikely that the transportation of radioactive materials will cause an additional fatality as a result of either incident-free transportation or associated with postulated transportation accidents.

- The highest risk estimate for any transportation activity is for the air transport of medical and industrial isotopes. Since the amount and nature of isotopes to be produced is uncertain, this analysis is necessarily conservative. However, in order for an isotope production facility to be successful, it is likely that large amounts of isotopes would be transported to locations throughout the country. All isotopes were assumed to be transported by air for the purpose of analysis.

- Options in which the processing and fabrication facility and the irradiation facility are collocated, such as Alternative 1, Options 3 and 6 and Alternative 2, Options 2, 7, and 8, have lower transportation risks than other alternatives.

- Options in which the irradiation facility is at an unspecified site, such as Alternative 2, Options 4, 5, and 6, and Alternatives 3 and 4, appear to have higher risks than other options. However, if an actual radiation facility is sited nearby the processing and fabrication facility, the risk estimates would be considerably lower.

- The overland transportation impacts are somewhat higher if mixed oxide fuel is accepted at east coast ports rather than a west coast port. The sea transportation impacts are much lower than overland transportation risks for shipment to either coast. The sea transportation impacts for western ports are double those for eastern ports. Use of the Panama Canal for shipment to western ports poses safeguards and security concerns.

J.8 UNCERTAINTY AND CONSERVATISM IN ESTIMATED IMPACTS

The sequence of analyses performed to generate the estimates of radiological risk for transportation includes: (1) determining the inventory and characteristics, (2) estimating shipment requirements, (3) determining route characteristics, (4) calculating radiation doses to exposed individuals (including estimation of environmental transport and radionuclides uptake), and (5) estimating health effects. Uncertainties are associated with each of these steps. Uncertainties exist in the way that the physical systems being analyzed are represented by the computational models; in the data required to exercise the models due to measurement errors, sampling errors, natural variability, or unknown simply caused by the future nature of the action being analyzed; and in the calculations themselves (e.g., approximate algorithms used by the computer). In principle, one can estimate the uncertainty associated with each input or computational source and predict the resultant uncertainty in each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final, or absolute, result. However, conducting such a full-scale quantitative uncertainty analysis is often impractical and sometimes impossible, especially for actions to be initiated at an unspecified time in the future. Instead, the risk analysis is designed to ensure, through uniform and judicious selection of scenarios, models, and input parameters, that relative comparisons of risk among the various alternatives are meaningful. In the transportation risk assessment, this design is accomplished by uniformly applying common input parameters and assumptions to each alternative. Although considerable uncertainty is inherent in the absolute magnitude of the transportation risk for each alternative, much less uncertainty is associated with the relative differences among the alternatives in a given measure of risk.

In the following sections, areas of uncertainty are discussed for the assessment steps listed above. Special emphasis is placed on identifying whether the uncertainties affect relative or absolute measures of risk. The degree of reality conservatism of the assumption is addressed. Where practical, the parameters that most significantly affect the risk assessment results are identified.

J.8.1 Uncertainties and Conservatism in Neptunium-237 and Plutonium-238 Inventory and Characterization

The inventories and the physical and radiological characteristics are important input parameters to the transportation risk assessment. The potential amount of transportation for any alternative is determined primarily by the projected dimensions of package contents, strength of the radiation field, heat that must be dissipated, and assumptions concerning shipment capacities. The physical and radiological characteristics are important in determining the amount of material released during accidents and the subsequent doses to exposed individuals through multiple environmental exposure pathways.

Uncertainties in the inventory and characterization will be reflected to some degree in the transportation risk results. If the inventory is overestimated (or underestimated), the resulting transportation risk estimates also will be overestimated (or underestimated) by roughly the same factor. However, the same inventory estimates are used to analyze the transportation impacts of each of this NI PEIS alternatives. Therefore, for comparative purposes, the observed differences in transportation risks among the alternatives, as given in Table J–6, are believed to represent unbiased, reasonably accurate estimates from current information in terms of relative risk comparisons.

If DOE should enter into the final design and implementation phase of the project, the amount of neptunium and plutonium in the targets could change. The incident-free risk estimate would not change, unless the number of shipments changes, because the maximum regulatory limit dose rate was used.

J.8.2 Uncertainties in Containers, Shipment Capacities, and Number of Shipments

The amount of transportation required for each alternative is based in part on assumptions concerning the packaging characteristics and shipment capacities for commercial trucks and SST/SGTs. Representative shipment capacities have been defined for assessment purposes based on probable future shipment capacities. In reality, the actual shipment capacities may differ from the predicted capacities such that the projected number of shipments and, consequently, the total transportation risk would change. However, although the predicted transportation risks would increase or decrease accordingly, the relative differences in risks among alternatives would remain about the same.

J.8.3 Uncertainties in Route Determination

Representative routes have been determined between all origin and destination sites considered in this NI PEIS. The routes have been determined consistent with current guidelines, regulations, and practices, but may not be the actual routes that would be used in the future. In reality, the actual routes could differ from the representative ones in terms of distances and total population along the routes. Moreover, since materials could be transported over an extended period of time starting at some time in the future, the highway infrastructures and the demographics along routes could change. These effects have not been accounted for in the transportation assessment; however, it is not anticipated that these changes would significantly affect relative comparisons of risk among the alternatives considered in this NI PEIS. Specific routes cannot be identified in advance because the routes are classified to protect national security interests.

J.8.4 Uncertainties and Conservatism in the Calculation of Radiation Doses

The models used to calculate radiation doses from transportation activities introduce a further uncertainty in the risk assessment process. It is generally difficult to estimate the accuracy or absolute uncertainty of the risk assessment results. The accuracy of the calculated results is closely related to the limitations of the computational models and to the uncertainties in each of the input parameters that the model requires. The single greatest limitation facing users of RADTRAN 5, or any computer code of this type, is the scarcity of data for certain input parameters.

Uncertainties associated with the computational models are minimized by using state-of-the-art computer codes that have undergone extensive review. Because there are numerous uncertainties that are recognized, but difficult to quantify, assumptions are made at each step of the risk assessment process that are intended to produce conservative results (i.e., overestimate the calculated dose and radiological risk). Because parameters and assumptions are applied to all alternatives, this model bias is not expected to affect the meaningfulness of relative comparisons of risk; however, the results may not represent risks in an absolute sense.

To understand the most important uncertainties and conservatism in the transportation risk assessment, the results for all cases were examined to identify the largest contributors to the collective population risk.

Postaccident mitigative actions are not considered for dispersal accidents. For severe accidents involving the release and dispersal of radioactive materials in the environment, no postaccident mitigative actions, such as interdiction of crops or evacuation of the accident vicinity, have been considered in this risk assessment. In reality, mitigative actions would take place following an accident in accordance with EPA radiation protection guides for nuclear incidents (EPA 1992). The effects of mitigative actions on population accident doses are highly dependent upon the severity, location, and timing of the accident. For this risk assessment, ingestion doses are only calculated for accidents occurring in rural areas (the calculated ingestion doses, however, assume all food grown on contaminated ground is consumed and is not limited to the rural population). Examination of the severe accident consequence assessment results has shown that ingestion of contaminated foodstuffs contributes on the order of 50 percent of the total population dose for rural accidents. Interdiction of foodstuffs would act to reduce, but not eliminate, this contribution.

J.9 REFERENCES

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10 CFR Section 71.91, "Records," U.S. Nuclear Regulatory Commission.

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